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Postglacial ~~Environment~~ Paleoenvironment of Southern Alberta

University — Université
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Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée
M.Sc

Year this degree conferred — Année d'obtention de ce grade
1979

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THE UNIVERSITY OF ALBERTA

POSTGLACIAL PALEOENVIRONMENT OF SOUTHERN ALBERTA

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

FALL, 1979

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled POSTGLACIAL PALEOENVIRONMENT OF SOUTHERN ALBERTA submitted by PAMELA LYNN WATERS in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in GEOLOGY.

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Supervisor

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Date Oct. 17, 1977

Abstract

In a widespread area of southwestern Alberta, paleosols have been recognized in post-glacial sediments. These deposits consist of alluvial, colluvial and lacustrine material. In many cases, a layer of tephra occurs either directly in contact with, or a few centimetres above the paleosols.

Examination of eight sections reveals that, at seven localities, primary Mazama ash overlies the paleosols. At the remaining locality, the ash is Mazama, but it has been reworked to some extent. This suggests that the paleosols are penecontemporaneous profiles. The paleosols have been identified as either of the Chernozemic Order or the Regosolic Order. Phytoliths contained in the Ah horizons indicate a vegetative suite dominated by short grasses.

Interpretation of the data suggests these soils developed under a warmer and drier climate than the present. This development indicates a period of non-depostion, when a stable landscape existed over southern Alberta. This period of climatic amelioration appears to represent the Altithermal Interval in Western Canada. Yet, the immature nature of the soils supports the idea of the period being short-lived, ending by the time of Mazama ash deposition (6600 years B.P.). Sedimentation resumed and appears continuous with no other major periods of soil development until the present day profile.

Aknowledgements

The author gratefully acknowledges the guidance and encouragement offered by Dr. N.W. Rutter during all phases of this project.

My thanks also goes to the following for their technical assistance: Dr. J. Dormaar, Lethbridge Agricultural Station; and from the University of Alberta; Dr. C. Schweger, Deptartment of Anthropology; Dr. S. Pawluk, Department of Soil Science; Dr. D.G.W. Smith, Department of Geology; Mr. G. Braybrook (Scanning ElectronMicroscope), Department of Entomology; and Mr. S. Launspach (Electron Microprobe), Department of Geology.

I also appreciate the wonderful perseverence of my typists Kasia Hedinger and Deborah Mills. Finally, I would like to thank my husband Bim not only for his help with the laboratory work, drafting and computing, but also for his patience and understanding during this ordeal.

Funding for this project was provided by E.M.R. grant 5537041.

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I. Introduction

In the past, many workers investigating glacial and postglacial deposits of Southern Alberta, have noted the presence of dark organic horizons within postglacial stratigraphic sequences exposed along cutbanks, in coulees and during excavations (Figure 1). These horizons have usually been referred to as paleosols.

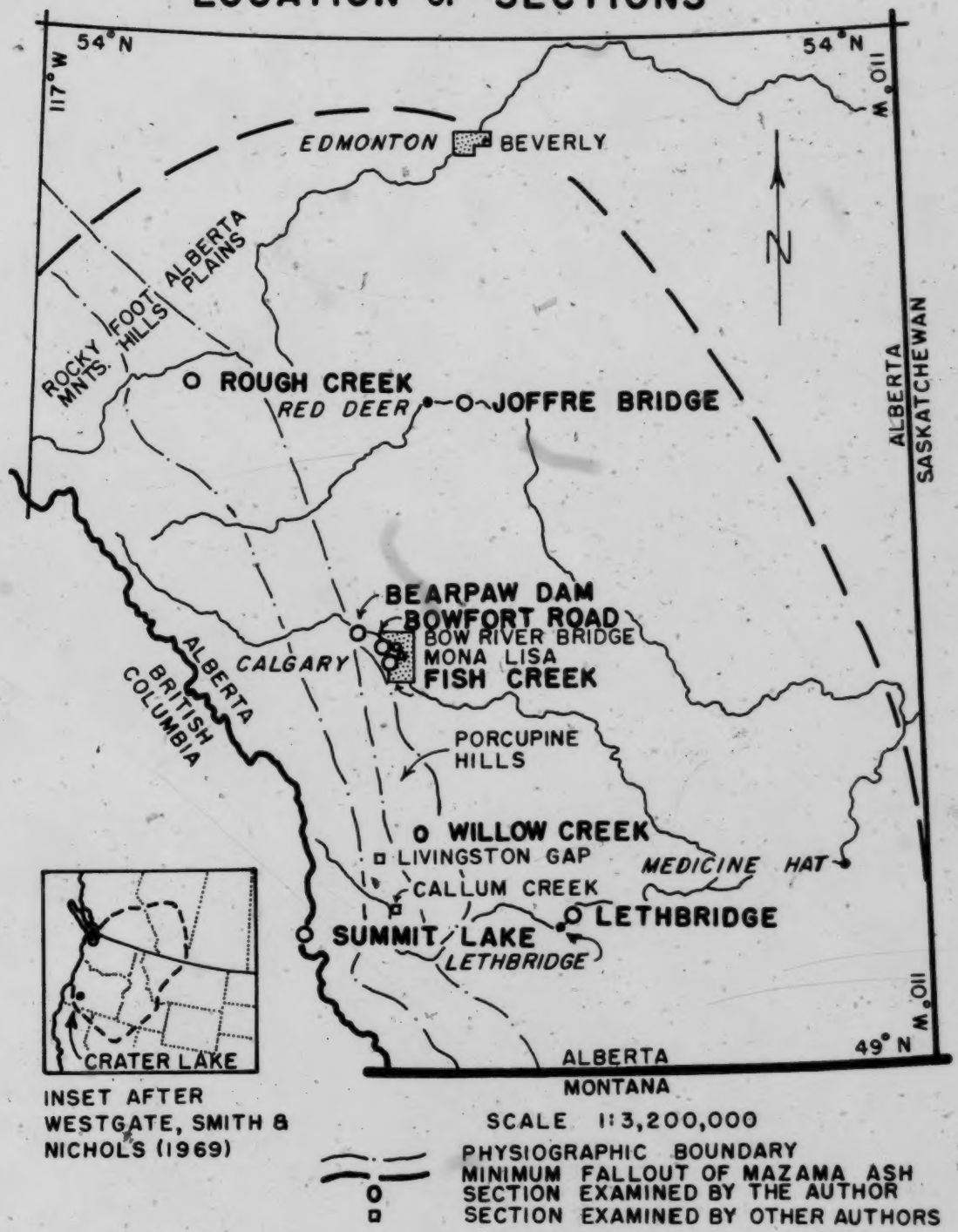
Commonly associated with these paleosols either directly above or a few centimeters above are tephra layers. Workers noting this occurrence assumed the tephra to be the same at each location and therefore tentatively interpreted the paleosols as being time equivalent. This is believed to represent a period of nondeposition and soil development.

A. Objectives of Study

The objectives of this study were threefold:

1. To identify and characterize the ash layers. This is in order to show that the ashes are time equivalent as opposed to being the result of different eruptions. Once this relationship is established the time equivalency of the soils can be determined.
2. To obtain paleoenvironmental information from the paleosols.
3. To try to reconstruct a regional postglacial history.

FIG. 1
LOCATION OF SECTIONS



INSET AFTER WESTGATE, SMITH & NICHOLS (1969)

SCALE 1:3,200,000

PHYSIOGRAPHIC BOUNDARY
MINIMUM FALLOUT OF MAZAMA ASH
SECTION EXAMINED BY THE AUTHOR
SECTION EXAMINED BY OTHER AUTHORS

In order to obtain field locations, workers were asked to identify localities where these paleosols had been noted. The eight most accessible sites were selected from approximately 18 reported. The sections which represent alluvial and colluvial sequences including the paleosols and tephra layers were described in the field and samples were collected. These samples were taken in order to further characterize the ashes, soils, and sediments in the laboratory. The eight sections that were investigated are shown in Figure 1.

B. Location and Physiography

The study area extends southward from Red Deer to Lethbridge, Alberta and westward into the Foothills. Three physiographic regions are represented (Figure 1). These are:

1. The Interior Plains.
2. The Rocky Mountain Foothills.
3. The Rocky Mountains.

The eastern section of the study area consists of part of the Alberta Plain, a subdivision of the Interior Plains Region. This is typified by fairly flat lying Mesozoic sandstones and shales. The bedrock is covered with varying thicknesses of glacial drift in the form of ground moraine, hummocky moraine and lateral and end moraines. Elevations vary between 750 and 1200 meters above sea level. The rivers drain to the east and are mainly incised and frequently

follow their preglacial channels. Many of the sections displaying the ash and associated paleosol are found along the cutbanks of these rivers. The Porcupine Hills are in the western part of the Alberta Plain. They are separated from the Foothills by a broad erosional valley. The hills are composed of gently dipping Tertiary strata, which have eroded to form a western facing cuesta. The Porcupine Hills are cut through in only two places, by the north and south branches of Willow Creek. Glacial material is found up the valleys of these creeks, but the tops of the hills were not glaciated. Cordilleran ice occupied the valley to the west, but was never thick enough to cover the hills.

To the west of the plains region is a narrow northwesterly trending belt of hills rising approximately 1300 to 2000 meters above sea level. This is the Rocky Mountain Foothills region. The hills are composed of folded and faulted Mesozoic sandstones and shales with glacial drift in the valleys. The glacial deposits are in the form of ground, end and lateral moraines laid down by valley glaciers. The Rocky Mountains occupy the most western part of the study area. The region consists of intensely faulted paleozoic carbonates and shales. The carbonates in particular, are exposed in multiple subparallel thrust faults which dip to the southwest. The mountains rise to elevations of 1500 to 2600 m above sea level. Many erosional glacial landforms such as aretes, horns, and U-shaped valleys are present. Materials which were deposited during

the advance and retreat of the many valley glaciers include, ground, lateral and end moraines, glacio-fluvial outwash sands and gravels and glacio-lacustrine silts and clays.

C. Climate

The plains region of the study area is typified by a subhumid continental climate which has short moderate summers and long cold winters, punctuated by warm dry Chinook winds spilling over the mountains. During the winter, the cold Arctic air mass moves south and is trapped against the mountains, which also blocks out the warm Pacific air from the west. Temperature changes can occur very rapidly. The average seasonal variation is from -9.5°C in January to 19°C in July. Precipitation in this area averages between 300 and 400 mm annually. This decreases to the south and east.

The Foothills and Mountain regions of the study area have a continental climate. It is typified by long cold winters and moderate summers. The direction of winds is predominantly from the west. This places the area in a rain shadow, which influences local precipitation. Mean annual precipitation throughout most of the area is between 500 and 600 mm with about half falling as snow. Temperature fluctuations are again considerable and rapid depending on the season and the day. Also, elevation is a very important factor. This is especially true in the mountains. The yearly

temperature varies between an average low of -11°C in January and an average high of 14.5°C in July.

D. Vegetation

The study area includes four phytogeographic regions. Rowe (1972) classifies these as the Grasslands, Boreal Forest, Subalpine and Alpine Tundra regions. On the plains, grasslands are predominant. Major vegetation is wheatgrass (Agropyron), fescue (Festuca) and needlegrass (Stipa), with a lesser abundance of blue grama (Bouteloua) and sedges (Carex). Shrubs of fringed sage (Artemisia frigida) and dwarf phlox (Phlox hoodii) are found in isolated patches. Within the Boreal Forest region, west of the grasslands, two sub-regions are distinguished. First, Aspen Parkland, which is a transitional area of grasses and trees. Trembling aspen (Populus tremuloides) is abundant, with balsam poplar (Populus balsamifera) and white birch (Betula papyrifera) in sparsely distributed patches. The second sub-region is the Upper Foothills, which is a narrow belt of forest lying parallel to the front ranges of the Rocky Mountains between the Aspen Parkland and the Subalpine Region. The Upper Foothills forests consist predominantly of lodgepole pine (Pinus contorta) and white spruce (Picea glauca). Though the forest is mainly coniferous, patches of deciduous trees common to the Aspen Parkland may be found. The Subalpine region on the east slopes of the Rockies is covered by a

coniferous forest. The major species are Engelmann spruce (Picea engelmannii), and alpine fir (Abies lasiocarpa). Lodgepole pine (Pinus contorta) is widespread in areas of regeneration following forest fires. At lower elevations, whitebark pine (Pinus albicaulis) and alpine larch (Larix lyalli) are common. Above 2000 m above sea level, the Subalpine region is gradually replaced by discontinuous Alpine Tundra. The vegetation consists mainly of dwarf shrubs, herbs, grasses and lichen.

E. Soils

The soils of the study area have developed as a result of localized environmental conditions. In the broadest sense, these conditions include climate and vegetation. As the climatic conditions change from east to west across the study area, the vegetation and soil types develop a related zonation. In the eastern part of the area, Black Chernozemic soils have developed under continuous tall grass cover. West of the grassland region, a mixed Aspen Parkland and grassland cover becomes predominant. Under this type of vegetation, Dark Gray Chernozems are developed. This transition is a reflection of cooling temperatures and increased moisture. With increased elevation, conditions for Aspen Parkland alone prevail and Dark Gray Luvisols are the major soil type. With the transition to a Luvisol:

1. The soil profile becomes thinner.

2. The amount of organic matter decreases.
3. The A horizon becomes more eluviated.
4. The illuviation increases in the B horizon.

In the foothills and mountains, the most common soils are Gray Luvisols and Eutric and Dystric Brunisols. Podzolic Soils are also common at high elevations. Most soils are developed in glacial drift, commonly till, fluvial silt, sand and gravel and lacustrine silt and clay.

F. Previous Investigations

Attempts to reconstruct the postglacial paleoenvironmental history of Alberta have been done using various approaches. Studies of pollen from peat bogs were done as early as 1949 by H.P. Hansen. More recently palynological studies have been undertaken by several workers. Most of this information has been compiled by Ritchie (1976). Harris and Pip (1973) reconstructed a postglacial history with the aid of molluscs. Fritz and Krouse (1973) also used molluscs in their oxygen isotope studies at Lake Wabamun.

Work on the paleosols of Alberta has been done by many researchers, Horberg (1952) first noted their occurrence in the postglacial sequences around Lethbridge. Rutter (1969), Lutwick and Johnston (1969), Pawluk and Dumanski (1969), Reeves and Dormaar (1972), Harrison (1973), Wilson (1974) and Dormaar (1978), have all described and analyzed many of

the paleosols in Southern Alberta.

The tephra layers, which are found throughout Southern Alberta are very important stratigraphic markers. One, in particular, Mount Mazama tephra, is very widespread in the study area (Figure 1). The source of this tephra is Crater Lake, Oregon (inset, Figure 1). The date of the eruption has been determined and is accepted to be 6600 years B.P. (Fryxell 1965). Mazama tephra deposits within Alberta have been described and subsequently analyzed by Westgate and Dreimanis (1967), Smith and Westgate (1969), Westgate, Smith and Nichols (1969) and Westgate (1977). These workers have developed a method for determining the chemical composition of the glass shards in a tephra. The composition of these shards is unique not only to a particular volcano but to a particular eruption.

Phytoliths are plant derived opals, which are deposited when the plant dies. The use of phytoliths in determining types of vegetation is a fairly new technique. Many workers are still trying to derive a system of taxonomy that would be useful to the level of speciation. At this time, the main divisions are at the subfamily level, which includes the tall (Panicoid) grasses, the short (Chloridoid) grasses, and the domestic (Festucoid) grasses. Wilding and Drees (1968), Twiss et al. (1969), Dormaar and Lutwick (1969), Lutwick (1971), Blackman (1972) and Rovner (1971) have all made attempts to identify and classify phytoliths in both modern day soils and paleosols.

II. Methodology

A. Field Methods

Field work was carried out during June and July 1977. Eight locations were chosen from those reported by N.W. Rutter (Summit Lake and Fish Creek), J.F. Dormaar (Willow Creek and Lethbridge), B.O.K. Reeves (Rough Creek and Joffre Bridge) and D.N. Proudfoot (Bearspaw Dam and Bowfort Road). At each site, which is accessible by road and a short walk, the regional setting, local physiography, modern soil profile and the surface vegetation were noted. After preparing a fresh surface, the colour, structure, texture and thickness of each sedimentary unit of the section was described and tentatively assigned an origin. Similarily, the paleosols were described, in the same way as outlined in The Canadian System of Soil Classification (Canadian Soil Survey Committee 1978) and tentatively classified. Bulk samples of each sedimentary unit, paleosol horizon and associated tephra were taken for laboratory analysis. Also, a monolith, which is an intact vertical soil section was removed at each of the sites. The section sampled extended from above the tephra down through the paleosol into the parent material. The monoliths were extracted by boxes 10 cm wide, 50 cm long and 12 cm deep. Sometimes more than one box was used in order to obtain the complete unit. The monoliths were removed by cutting a block approximately the size of the box, but deeper out of the fresh face. The box is then

shoved into place, and the monolith is trimmed away and removed from the face. The monoliths were brought back to the laboratory in case further information was needed to classify the soils.

B. Laboratory Analysis

Laboratory studies were undertaken to verify the field identifications of the sedimentary units and paleosols and to obtain data useful in the reconstruction of geological events.

Grain size was determined on all samples. From the separated sand fraction, molluscs were examined. Carbon and nitrogen determinations were done on each horizon of the paleosols. The Ah horizons underwent analyses for pollen and phytoliths. The volcanic ash was processed and its composition determined.

The distribution of grain size was determined for all samples using standard preparation, sieving and hydrometer techniques (Krumbein and Pettijohn 1938). This technique was used in order to verify the depositional environment of the sedimentary units.

The carbon and nitrogen determinations were done using the Modified Walkley-Black method and the semi-Micro Kjeldhal method respectively (McKeague 1978). These determinations were used to support the field classification of the paleosols.

Phytoliths were removed from the Ah horizons using the method of Jones and Beavers (1964). The 5 to 50 micron fraction was examined and photographed using a scanning electron microscope (Model Cambridge 150). Phytoliths are useful as paleoenvironmental indicators.

The Ah horizons were also processed for pollen material using the procedure developed by the University of Alberta Paleoenvironmental Group (Appendix I). Pollen, since it reflects the local vegetation at the time of soil formation, was thought to be useful as a paleoenvironmental indicator.

In order to determine the composition of the ash deposits the method outlined by Smith and Westgate (1969) was followed with a slight variation. After the light and heavy fractions were separated, the fraction containing the lighter material was then rolled down a piece of paper. This use of static electricity resulted in an increased concentration of glass shards. The shards remained on the paper while all other material would fall off. The remainder of the procedure was followed exactly and the shards were analyzed using an A.R.L. "EMX" electron microprobe.

III. Results

The following information is provided at the beginning in order to simplify the discussion of the results.

1. All soil horizon and profile classifications are based on the Canadian System of Soil Classification (1978). Therefore, all pertinant sections of this system are presented in Appendix II.
2. Since all the paleosols under discussion are buried, the suffix "b" has been dropped from all descriptions.

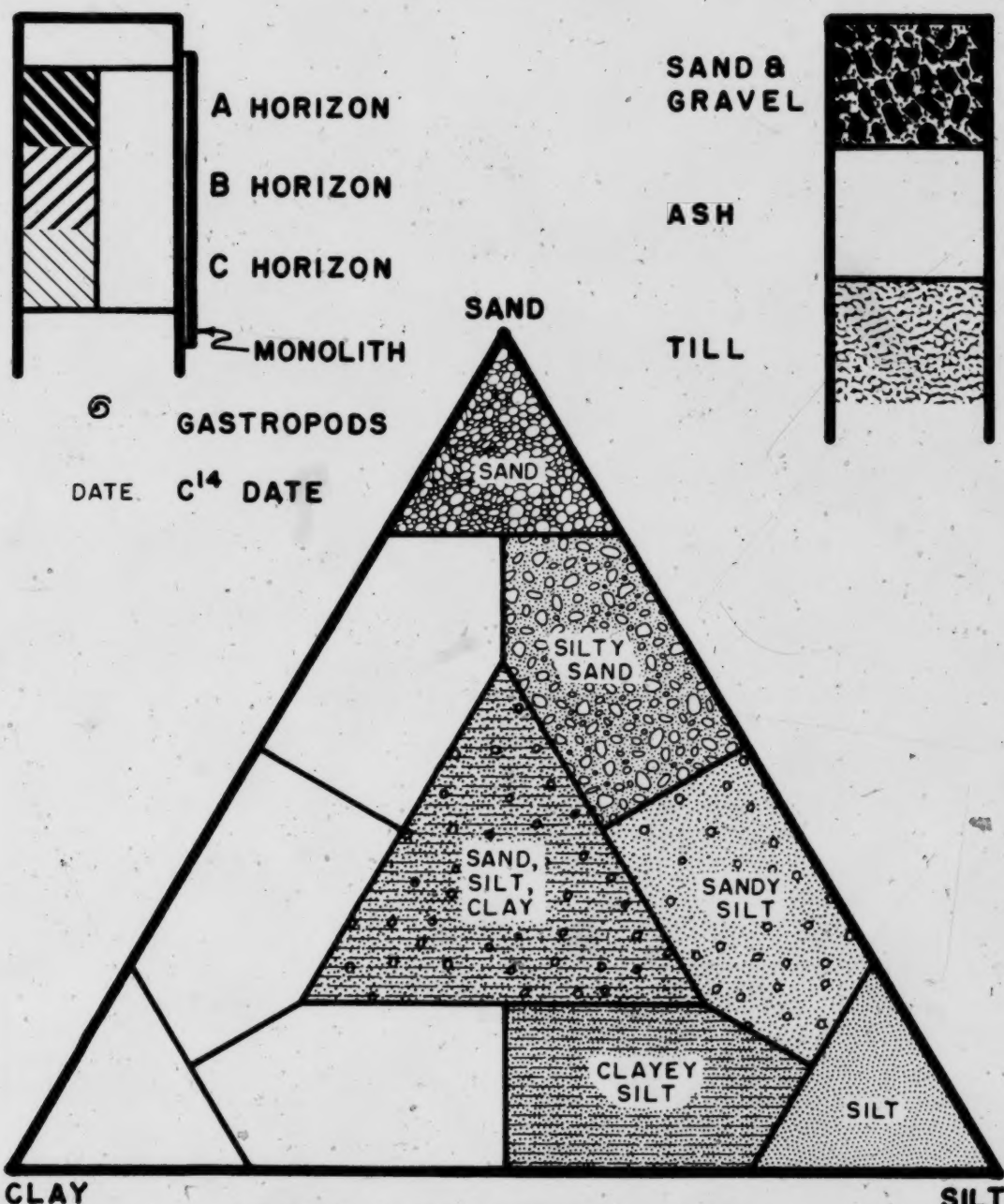
A. Willow Creek

The Willow Creek section is exposed along an abandoned cutbank of Willow Creek (Plate 1), located in the Porcupine Hills, approximately 24 km west of Stavely, Alberta (Figure 1). The general physiography of the area is shown in Plate 1.1. The section is developed in the uppermost river terrace. A flat area extends approximately 1 km back from the cliff. A complete stratigraphic column is given in Figure 3.

The lowest visible unit, WC-1, is till. It is greater than 300 cm thick, contains 5% pebbles and has a silty matrix (Table 1). The pebbles found in the till included crystallines derived from the Canadian Shield. Also, the glacial evidence shows that Cordilleran ice never reached the Porcupine Hills indicating the till is a Laurentide glacial deposit.

FIG.2

LEGEND



GRAIN SIZE DISTRIBUTION

(after Shepard, 1954)

Plate 1

1. View of the area of Willow Creek, looking toward the west, from the top of the section.

2. Section at the Willow Creek locality, with an ash (A), a paleosol (B) and the underlying till (C). (shovel for scale)

PLATE 1

Unit WC-2 overlies the till and contains the paleosol which is developed directly below the upper contact (Plate 1.2). The unit is 71 cm thick and grayish brown (10YR5/2 moist). The texture is mainly silty with equal parts of sand and clay at the bottom with increasing sand and decreasing silt and clay towards the top of the unit (Table 1). The unit is a floodplain deposit, since it is flat lying, of uniform thickness and poorly bedded. Supporting evidence is the presence of freshwater gastropods and pelecypods, which were found in the sand fraction towards the base of this unit (Figure 3). Pisidium and Gyraulus are aquatic molluscs whose habitat is slow moving, shallow water. They both have a geological range from the Upper Cretaceous to the Recent. The areal extent of modern occurrences in North America is large. It extends from Alaska to Florida and eastward from the Rockies. Dyke et al. (1965) report a radiocarbon date of 9290±260 years B.P. determined from the gastropods of this unit (Table 5).

The paleosol has an upper horizon 12 cm thick, very dark gray (10YR3/1 moist) and massive. Organic carbon content is 1.31% (Table 2) and nitrogen is .063% giving a C/N ratio of 20.7. This C/N ratio probably reflects a very high organic carbon content, which was present at the time of burial. In reporting the carbon and nitrogen content and resulting C/N ratios for the A horizons of the paleosols, an attempt has been made to provide as much information as

Table 1

Grain Size Analysis

Section	Sample Number	Sand %	Silt %	Silt+ Clay %	Clay %	Texture (Shepard 1954)
Willow Creek						
	1	70.0	22.8		7.2	silty sand
	2	44.3	39.5		16.2	silty sand
	4	25.6	53.6		20.8	sand,silt,clay
	5	25.3		74.7		sand,silt,clay
	6	37.1	45.9		17.0	sandy silt
	7	45.3		54.7		silty sand
	9	26.1	55.4		18.5	sandy silt(till)
Summit Lake						
	10	13.6	77.8		8.6	silt
	12	28.0	66.2		5.8	sandy silt
	13	17.0	68.1		14.9	sandy silt
	14	44.0	47.0		9.0	sandy silt
Lethbridge						
	15	28.9	53.3		17.8	sandy silt
	17	21.9	56.2		21.9	sand,silt,clay
	18a	12.1	64.2		23.7	clayey silt
	18b	11.2	55.1		33.7	clayey silt
	19	9.0	70.1		20.9	clayey silt

Table 1 (Cont.)

Grain Size Analysis

Section	Sample Number	Sand %	Silt %	Silt+ Clay %	Clay %	Texture (Shepard, 1954)
Fish Creek						
	21	2.1	78.3		19.6	silt
	22a	6.4	76.0		17.6	silt
	22b	5.6	65.3		29.1	clayey silt
	22c	11.7	65.3		23.0	clayey silt
Pearspaw Dam						
	23	28.6	62.8		8.6	sandy silt
	25	21.1	60.0		18.9	sandy silt
	26	17.5	69.3		13.2	sandy silt
	27	28.4	55.8		15.8	sandy silt
	28	24.3	62.8		12.9	sandy silt
	29	26.5	58.8		14.7	sandy silt
	30	49.0	44.4		6.6	silty sand
	31	17.2	64.6		18.2	clayey silt
Bowfort Road						
	33	36.7	49.4		13.9	sandy silt
	34a	36.6	54.5		8.9	sandy silt
	34b	28.3	54.5		17.2	sandy silt
	34c	31.6	49.2		19.2	sandy silt
	35	47.1	42.3		10.6	silty sand

Table 1 (Cont.)

Grain Size Analysis

Section	Sample Number	Sand %	Silt %	Silt+ Clay %	Clay %	Texture (Shepard 1954)
Fough Creek						
	37	25.5	68.5		6.0	sandy silt
	38	32.8	49.7		17.5	sandy silt
	39	28.0	54.0		18.0	sandy silt
	40	81.1		18.9		sand
	41	34.5	51.1		14.4	sandy silt
	42	31.5	60.3		8.2	sandy silt
	43	27.9	60.6		11.5	sandy silt
	44	78.0		22.0		sand
	45	33.1	48.8		18.1	sandy silt
	46	7.5	69.4		23.1	clayey silt
Joffre Bridge						
	48	7.9	79.2		12.9	silt
	50a	15.5	72.7		11.8	sandy silt
	50b	15.8	67.4		16.8	clayey silt
	50c	10.5	61.8		27.7	clayey silt
	50e	9.1	72.7		18.2	clayey silt
	51	42.7	56.7		0.6	sandy silt

possible. The problems associated with carbon and nitrogen determinations in a buried soil, which have been discussed by Pawluk (1978), could indicate that the carbon and nitrogen values do not reflect the original content, but may reflect changes occurring after burial. The horizon just described was classified as an Ah and with the additional information provided by the phytoliths (Chapter I) can be classified as a chernozemic Ah. Below the Ah horizon is a 9 cm thick, pale brown (10YR6/3 moist), massive horizon. This is the Ahej. The next horizon is 15 cm thick, buff (10YR4/3 moist) with slight iron staining and massive, indicating a Btj. The granulometric data (Table 1) shows an increase in clay from the overlying eluviated Ahej horizon to this horizon of about 4%. The horizon below the Btj is 35 cm thick, grayish brown (10YR5/2 moist) and massive. This is the C horizon. The soil was classified as an Eluviated Black Chernozem based on the horizons already described. The climatic and vegetational implications of this soil type are well within the range of conditions for a modern Black Chernozem. This includes a mean annual soil temperature of 2°C to <8°C and a mean summer soil temperature of 8°C to <18°C. The moisture regime is subhumid indicating soils which are occasionally dry when the soil temperature is ≥5°C.

Unit WC-3 overlies the paleosol and contains the ash deposit (Plate 1.2). The unit is 106 cm thick, 14 cm is below the ash and 78 cm is above the ash (Figure 3). It is a

Table 2
Carbon Content

Section	Sample Number	Sample Weight (gm)	ml FeSO4 Titrated	Carbon Weight (gm)	% C
Willow Creek					
	4	2.3295	14.6	.0098	.42
	5	2.1350	14.6	.0097	.45
	6	.9220	13.25	.0121	1.31
	7	.9606	15.4	.0084	.87
	8	.9964	16.5	.0065	.65
Summit Lake					
	12	1.8451	5.6	.0255	1.38
	13	2.4746	14.5	.0100	.40
	14	2.2331	14.4	.0100	.45
Lethbridge					
	18a	2.0706	12.0	.0143	.69
	18b	1.9347	12.5	.0133	.68
	19	1.9180	14.9	.0091	.47
Fish Creek					
	22a	1.8980	3.7	.0288	1.52
	22b	1.7890	11.55	.0151	.84
	22c	1.8622	13.90	.0109	.59
Bearspaw Dam					
	23	1.8491	8.75	.0200	1.08
	27	1.8623	15.25	.0086	.46
	28	2.0430	13.6	.0114	.56
	29	1.9523	13.0	.0125	.64

Table 2 (Cont.)

Carbon Content

Section	Sample Number	Sample Weight (gm)	ml FeSO4 Titrated	Carbon Weight (gm)	% C
Bowfort Road					
	34a	1.0394	14.45	.0100	.96
	34b	1.9790	12.4	.0136	.69
	34c	1.8399	13.5	.0117	.64
	35	2.1198	16.8	.0058	.27
Rough Creek					
	37	1.5123	8.3	.0207	1.37
	38	1.9189	9.65	.0184	.96
	39	.9940	13.9	.0110	1.12
Joffre Bridge					
	50b	1.9942	7.8	.0216	1.08
	50c	1.9403	15.6	.0079	.41
	50e	1.7230	13.0	.0122	.71
	51	2.1258	16.2	.0068	.32
	Blank	-	20.1	-	-

Carbon wt. = 0.00176(ml FeSO4 for blank - ml FeSO4 titrated)

% C = 100(Carbon wt.)/(sample wt.)

Table 3
Nitrogen Content

Section	Sample Number	Sample Weight (gm)	ml Titrated	H_2SO_4 Normality	% N
Willow Creek					
	4	.4993	2.02	0.01	.057
	5	.5001	0.30	0.1	.084
	6	.4995	2.24	0.01	.063
	7	.5009	0.28	0.1	.078
	8	.5009	3.65	0.01	.102
Summit Lake					
	12	.4993	4.78	0.01	.134
	13	.5002	1.35	0.01	.038
	14	.5000	1.10	0.01	.031
Lethbridge					
	18a	.5000	3.03	0.01	.085
	18b	.5002	2.86	0.01	.080
	19	.5003	2.16	0.01	.060
Fish Creek					
	22a	.4995	5.76	0.01	.161
	22b	.5005	3.85	0.01	.108
	22c	.5002	2.32	0.01	.065
Bearspaw Dam					
	23	.4995	3.65	0.01	.102
	27	.5007	2.25	0.01	.063
	28	.5005	2.40	0.01	.067
	29	.4995	2.98	0.01	.084

Table 3 (Cont.)

Nitrogen Content

Section	Sample Number	Sample Weight (gm)	ml Titrated	H_2SO_4 Normality	% N
Fowfort Road					
	34a	.5010	3.36	0.01	.094
	34b	.5002	2.52	0.01	.071
	34c	.4993	2.76	0.01	.077
	35	.5005	1.50	0.01	.042
Rough Creek					
	37	.5005	6.38	0.01	.178
	38	.4995	2.77	0.01	.078
Joffre Bridge					
	50b	.4997	6.32	0.01	.177
	50c	.4997	2.24	0.01	.063
	50e	.5005	2.91	0.01	.081
	51	.4997	2.85	0.01	.080
	Blank	-	0.56	0.01	.008
	Blank	-	0.55	0.01	.008

1 ml of 0.01 Normal H_2SO_4 = 140 micrograms of Nitrogen

% N = 100(0.000140(ml titrated))/(sample weight)

gray brown (10YR5/2 moist) silty sand deposit (Table 1). This is alluvium because it is flat lying, of uniform thickness and thinly bedded. The ash layer WC-3a (Figure 3) has been diluted with silt and sand. This is due to mixing during transport and redeposition of the ash unit. It is 14 cm thick and pale brown (10YR6/3 moist). In processing the sample for microprobe analysis, few glass shards were found. This is because the glass has undergone devitrification which alters the specific gravity. In examining the shards under a binocular microscope, the habit of the shards as well as the associated heavy minerals, including hornblende, orthopyroxene, clinopyroxene and magnetite, indicate that it is Mazama ash (J. Westgate, University of Toronto, pers. commun., 1979). This tephra has a reported age of 6600 years B.P. (Fryxell 1965).

Unit WC-4 is the uppermost unit. It is dark gray (10YR4/1 moist) and consists predominantly of sand with minor amounts of clay (Table 1). The upper 6 cm is very sandy and [illegible]epresent wind blown deposits stabilized later by vegetat[illegible] The unit is thickly bedded, accentuated by four organic horizons (Figure 3) which are dark brown (10YR5/2 moist). This is a floodplain deposit. The modern profile was identified in the field as a Humic Regosol.

E. Summit Lake

During the maintenance of the railroad line through the Crowsnest Pass, a section containing a utility pole was left exposed (Plate 2.1). It is located 100 m south of Highway 3, 1.6 km west of the Alberta-British Columbia border (Figure 1). The section is in the flat bottom of a mountain pass, which is fairly narrow with steep sides. A complete stratigraphic column is given in Figure 4.

SL-1 (Figure 4) is the lowest visible unit and contains the paleosol. The deposit is 43 cm thick, brown (10YR4/3 moist) and has a silty texture. The silt does contain a high percentage of sand at the base which decreases toward the top of the unit (Table 1). It is a floodplain deposit which is flat lying and of uniform thickness. The presence of terrestrial gastropods (Figure 4), particularly intact Vallonia supports this conclusion. Vallonia is found from Southern Canada to Texas. It is found in the wooded sections related to both upland and floodplain situations. It is found in sediments from the Pleistocene to the Recent.

The paleosol has an upper horizon 6 cm thick, very dark gray (10YR3/1 moist), and also massive. The organic carbon content is 1.38% (Table 2) and the nitrogen content is 1.34% (Table 3). The C/N ratio is 10.3. The horizon is an Ah, most likely a chernozemic Ah, since the phytolith data indicates that short grasses grew on this surface. The thin nature of this horizon may be the result of erosion following the

FIG. 3

WILLOW CREEK

NE 1/4 S6 T14 R39 W4

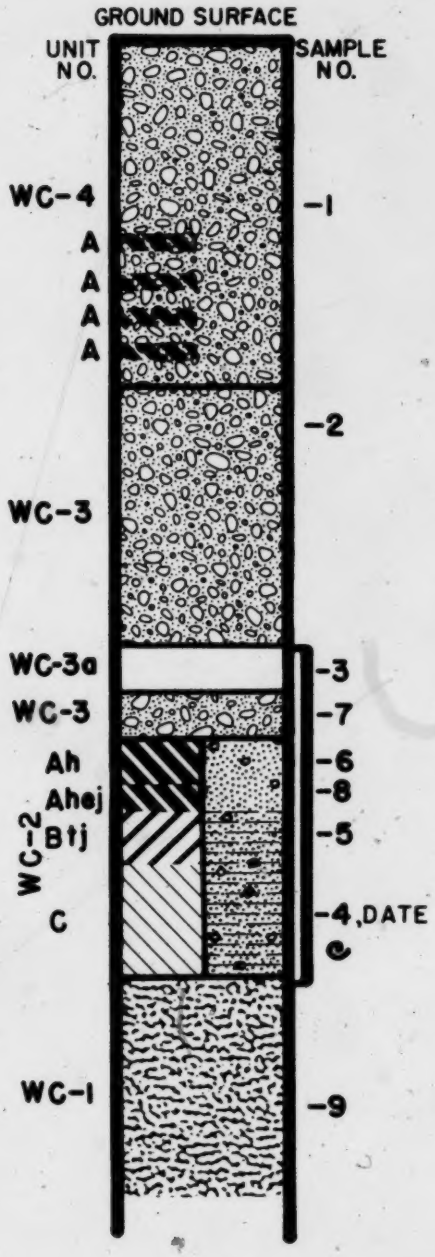
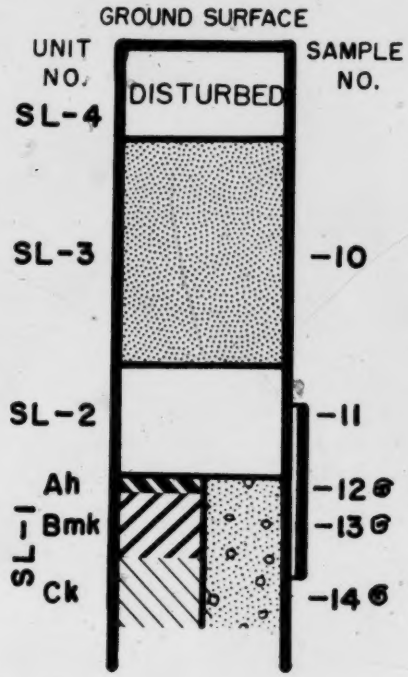


FIG. 4

SUMMIT LAKE

NW 1/4 S6 T8 R6 W5



SCALE 1:20

SEE FIG. 2 FOR LEGEND

Table 4

Chemical Composition of Volcanic Glass in Ash Samples as Determined by Electron Probe

Oxide	Sample number 11a	16	20	24	32	36	49	Average Mazama Ash*
SiO2	73.12	72.69	73.08	73.28	72.82	72.81	73.07	72.59±0.27
TiO2	0.40	0.41	0.41	0.41	0.40	0.37	0.37	0.48±0.02
Al2O3	14.25	14.69	14.28	14.72	14.34	14.44	14.25	14.42±0.16
FeO	2.03	2.08	2.05	2.01	1.98	1.97	2.02	2.08±0.08
MgO	0.47	0.47	0.47	0.46	0.52	0.51	0.46	0.54±0.08
CaO	1.63	1.64	1.59	1.60	1.66	1.58	1.62	1.71±0.09
Na2O	5.12	5.03	5.13	4.63	5.32	5.34	5.27	5.15±0.16
K2O	2.81	2.85	2.85	2.77	2.81	2.82	2.78	2.70±0.06
Cl	0.20	0.20	0.20	0.18	0.21	0.20	0.20	0.18±0.02
								(58 ANALYSES)

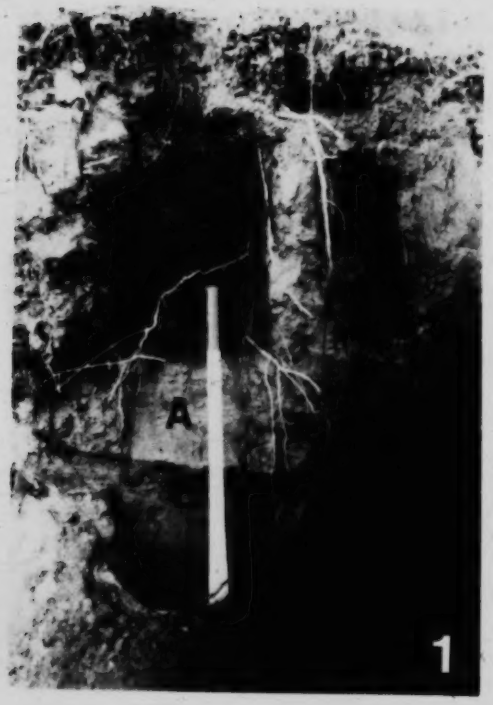
*(after Westgate, Smith and Nichols 1969)

Plate 2

1. Section through the post-glacial sequence at the Summit Lake locality, with an ash (A) and a paleosol (B). (pick for scale)

2. Close-up view of the contact between the ash (A) and the A horizon of the paleosol (B). (distance between arrows is 10 cm)

PLATE 2



period of soil development. The underlying horizon is 17 cm thick, light brown (5YR5/3 moist) and massive. Minor oxidation and the presence of carbonate as shown by the addition of dilute HCl indicate a Bmk horizon. Below the Bmk, the unit is greater than 20 cm thick, brown (10YR4/3 moist) and contains carbonate. This is a Ck horizon. This profile is classified as a Calcareous Black Chernozem. The temperature and moisture regime for this soil type is the same as that of Willow Creek.

Unit SL-2 is the tephra layer. It is 28 cm thick and yellowish brown (10YR6/3 moist). The upper 14 cm of the deposit appear to be less diluted with terrigenous material than the bottom 14 cm. This may be due to reworking of the upper part of the layer after initial deposition. The glass shards recovered from the ash were analyzed and the results indicate that three distinct groups of shards are present. The most abundant group (85%) shows a chemical composition the same as that reported for Mazama ash (Table 4). The other two groups of shards were not abundant enough to classify, but support the idea that the layer has been reworked.

SL-3 is the unit overlying the ash. It is 65 cm thick, dark yellowish brown (10YR4/4 moist) and has a texture which is mainly silty with minor sand (Table 1). The dark colour (Plate 2.1) is due to the high organic detritus dispersed throughout the deposit. The unit is classified as alluvium because it is flat lying, of uniform thickness and massive.

Table 5

Radiocarbon dates

Laboratory Dating No.	Date Years BP	Location	Collector	Material	Fig
GSC-236	9290±260	Willow Creek	A.M. Stalker	freshwater gastropod shells	3
GSC-1819	8400±150	Bowfort Road	J.F. Harrison	carbonized twig fragments	8
GSC-1944	8030±200	Rough Creek	B.O.K. Reeves	charcoal	9
GX-0956	9570±240	The Gap	B.O.K. Reeves and J.F. Dormaar	charred bison cervical vertebrae	1
GSC-1158	8050±150	The Gap	B.O.K. Reeves and J.F. Dormaar	charcoal	1
GSC-1209	8080±150	Mona Lisa	M. Wilson	bison bone	1

The uppermost unit, SL-4 is 28 cm thick and is not classified because of disturbance during work on the railroad.

C. Lethbridge

The Lethbridge site is located on the west side of a coulee (Plate 3.1), which is a tributary of the Old Man River. It is approximately 9.6 km north of the city of Lethbridge (Figure 1). The section is developed in a high terrace of the Old Man River. The area is flat prairie and under cultivation.

The lowest visible unit, LB-1 is a till (Figure 3). This till forms the ground moraine in the Lethbridge area (Horberg 1952). Above the till, unit LB-2, is a varved glacial lake sequence. Horberg (1952) called this deposit the Lake Lethbridge Silt.

The first unit described in detail and sampled is LB-3. It is a clayey silt with the middle section being clay enriched (Table 1). It is an alluvial sequence which is flat lying and thinly bedded.

The paleosol is developed in this unit (Figure 5). The upper horizon is 22 cm thick, very dark grayish brown (10YR3/2 moist) and is massive. The organic carbon content is .69% (Table 2) and the nitrogen is .085% (Table 3). This gives a C/N ratio of 8.1. The above criteria show that this horizon is an Ah. Below the Ah, the unit is 16 cm thick,

FIG. 5

LETHBRIDGE

SE 1/4 S4 T10 R21 W4

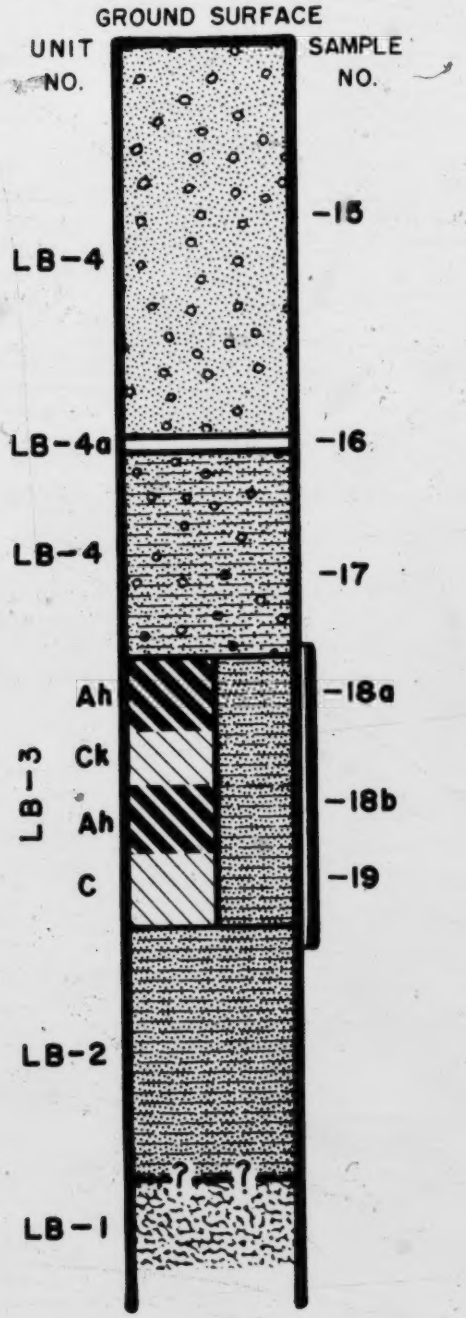
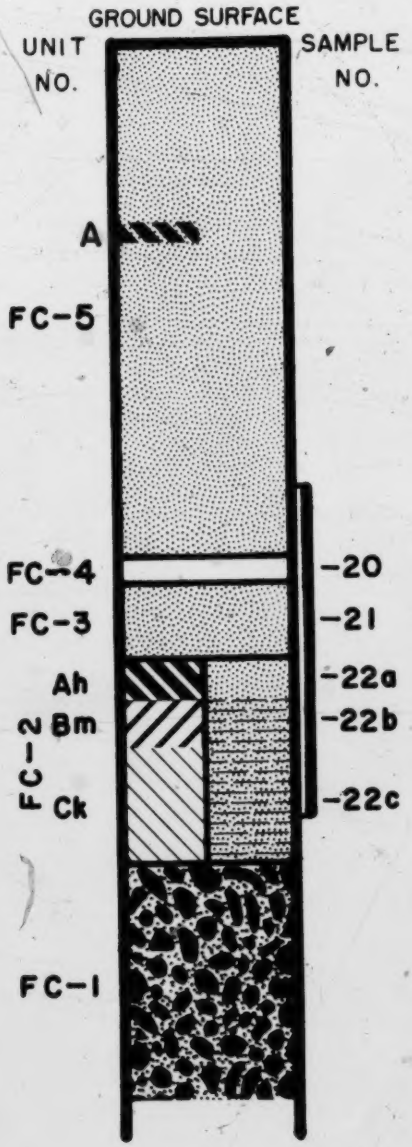


FIG. 6

FISH CREEK

SW 1/4 S4 T23 R1 W5



SCALE 1:20

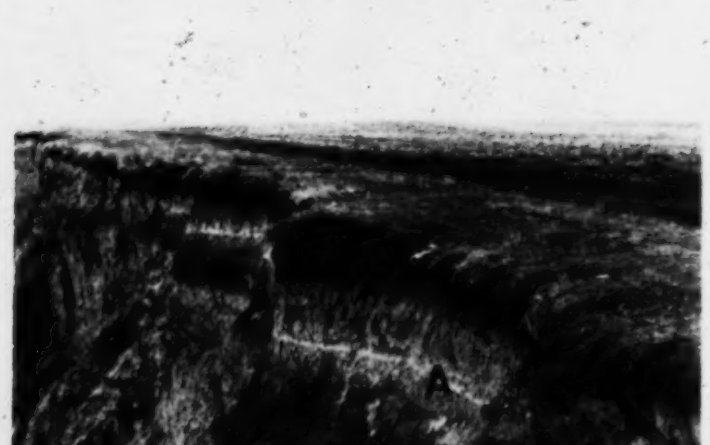
SEE FIG. 2 FOR LEGEND

Plate 3

1. View of the Lethbridge section, looking toward the west. An ash (A) and a paleosol (B) can be distinguished. (station wagon for scale)

2. Closer view of the Lethbridge section with the ash (A) and the paleosol (B).

PLATE 3



yellowish brown (10YR5/4 moist) and is massive. A slightly higher concentration of carbonate is found in this horizon. This is seen when dilute HCl is added to the material. This horizon effervesces more strongly than any of the others. It is a Ck horizon. The next horizon (Figure 5) is 25 cm thick, very dark grayish brown (10YR3/2 moist) and is massive. The carbon content is .68% (Table 2) and nitrogen content is .080% (Table 3). This gives a C/N ratio of 8.5. This horizon is a second Ah. The soil is classified as a Cumulic Humic Regosol. These soils are found under various climatic regimes.

The unit above the paleosol, LB-4, is 180 cm thick and contains the ash (Plate 3.2). The lower 60 cm of the unit has a sand, silt, clay texture (Table 1), and is dark grayish brown (10YR4/2 moist). It is classified as alluvium because it is flat lying, of uniform thickness and thinly bedded.

Unit LB-4a is the ash deposit. It is 5 cm thick and pale brown (10YR6/3 moist). The recovered shards were analyzed and found to have a chemical composition coinciding with that of Mazama ash (Table 4). The uppermost 15 cm of the unit LB-4 consists of sandy silt differing only slightly from the lower part of the unit (Table 1). The slight increase in sand and the corresponding decrease in silt and clay content probably indicates a minor change in the source or energy regime of the river. The modern profile has an Ap horizon and was identified in the field as a Dark Brown

Chernozem.

D. Fish Creek

The section at Fish Creek is exposed along a cutbank on the south side of Fish Creek (Plate 4.1). The site is approximately .8 km east of Highway 2 where it crosses Fish Creek (Figure 1). Fish Creek is a small easterly flowing stream, incised into postglacial gravels. The section is flat on top, but the slope increases quite steeply to the west.

The lowest unit FC-1 consists of 1 m of highly imbricated gravels with interstitial coarse sand (Figure 6). It is flat lying and the sediments are moderately well sorted and bedded. The upper contact is horizontal (Plate 4.2). These gravels are typical of eastward flowing high energy postglacial streams that have incised the glaciated surface.

The unit above the gravels, FC-2, is an olive colour (5Y5/3 moist) and consists of clayey silt with varying clay content (Table 1). The upper part of the unit is deficient enough in clay content to be classified as a silt (Figure 6). The thickness of the unit decreases from 70 to 10 cm towards the east. The deposit contains approximately 2% pebbles scattered randomly throughout the unit. The scattered pebbles and downslope thinning indicate that this deposit is most likely colluvium.

Plate 4

1. Section through the post-glacial sequence at the Fish Creek locality, with an ash layer (A), a paleosol (B), and at the base of the section, fluvial sands and gravels (C).

2. Close-up view of the section showing the relationship between the ash (A) and the paleosol (B). Fluvial sands and gravels are at the base of the section (C). (shovel for scale)

PLATE 4

The paleosol is developed in the upper part of this unit. The upper horizon (Figure 5) is 12 cm thick, very dark grayish brown (10YR3/2 moist) and is massive (Plate 4.2). The organic carbon content is 1.52% (Table 2) and the nitrogen content is .161% (Table 3). This gives a C/N ratio of 9.4. Therefore, the horizon is classified as an Ah. The phytolith material from this horizon indicates a grassland vegetation, probably associated with a chernozemic Ah. The horizon below the Ah is 13 cm thick, brown (10YR4/3 moist) and is massive. The horizon has undergone slight illuviation (Table 1). This can be shown by the increase in clay content between the Ah horizon and this horizon. This horizon also has a redder hue than the underlying horizon. Thus it has been classified as a Bm. The parent material appears to vary, as the unit thins to the east. The soil eventually becomes developed in the sand and gravels. The carbonate content in this horizon seems to have increased when compared visually to the other horizons. Therefore, it is a Ck horizon. This soil is classified as an Orthic Dark Brown Chernozem. The temperature regime for this soil type is the same as that of the Black Chernozems given in the Willow Creek chapter. The moisture regime is different. It is characterized by more frequent periods of moisture deficiency.

The unit above the paleosol, FC-3, is grayish brown (2.5Y5/2 moist) and silty (Table 1). It decreases in thickness from 80 to 0 cm towards the east. The downslope

thinning seems to indicate that the deposit is colluvium.

The next unit above, FC-4, is the ash deposit. It is 8 cm thick and is a white colour (10YR8/2 moist) in the more concentrated zones and pinker in the zones diluted by silt. The shards were analyzed and shown to have a chemical composition comparable to that reported for Mazama ash (Table 4).

The uppermost unit, FC-5, has a silty texture (Table 1). It is a slightly concave deposit (Plate 4.1), appearing to have filled a shallow depression. It is an alluvial deposit because it is thinly bedded and fairly flat lying. An Ah band 5 cm thick is found three-quarters of the way up the unit. It is laterally continuous throughout the section. The modern profile is a Cumulic Rego Chernozem (Dormaar, 1978).

E. Bearspaw Dam

The section at Bearspaw Dam is on the south side of Bow River, approximately 0.6 km upstream from the dam (Figure 1). The surrounding area is rolling, treeless prairie. The land is under cultivation.

The lowest unit, BD-1, (Figure 7), is greater than 30 cm thick, olive (5Y5/3 moist) and has a clayey silt texture (Table 1). It is classified as an alluvial deposit since it is flat lying and thinly bedded. The next unit, BD-2, is 26 cm thick, olive (5Y5/3 moist) and is a silty

sand (Table 1). It is classified as an alluvial sequence for the same reasons given for unit BD-1.

BD-3 overlies BD-2. It is 51 cm thick and has a sandy silt texture. It is thinly bedded, of uniform thickness and contains intact terrestrial gastropods. The two common genera are Vallonia and Retinella. Vallonia inhabits the wooded sections of floodplain and upland areas. Retinella is also associated with moist environments. This indicates a floodplain environment for this deposit. The paleosol is developed in this unit (Plate 5.2).

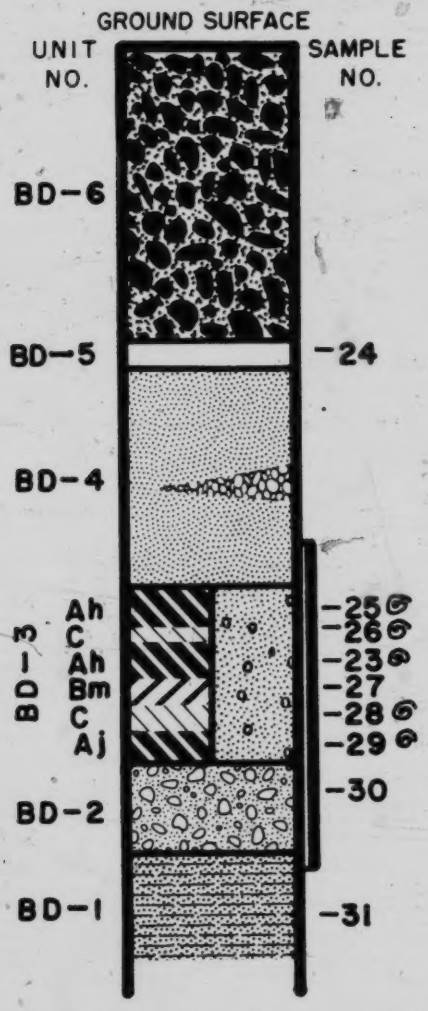
The uppermost horizon is 11 cm thick, dark brown (10YR3/3 moist) and has a massive structure common to all the horizons of this soil. This is an Ah horizon. The next horizon is 5 cm thick and a brown colour (10YR5/3 moist). This is classified as a C horizon. The second organic horizon is 10 cm thick and a very dark grayish brown (10YR3/2 moist). The organic carbon content of this horizon is 1.08% (Table 2) and the nitrogen content is .102% (Table 3). The C/N ratio is 10.6. This horizon is an Ah, which grades down into a 7 cm thick unit. This unit is a strong brown colour (7.5YR5/8 moist) and is indicative of a Bm horizon.

The next horizon below the Bm is 9 cm thick and has a yellowish brown colour (10YR5/4 moist). It is a C horizon. A weak organic horizon is developed in the lowest part of BD-3. It is 9 cm thick and dark brown (10YR3/3 moist). It has an organic carbon content of .64% (Table 2) and a

FIG. 7

BEARSPAW DAM

NE 1/4 S1 T25 R3 W5



SCALE 1:20

SEE FIG. 2 FOR LEGEND

FIG. 8

BOWFORT ROAD

SE 1/4 S26 T24 R2 W5

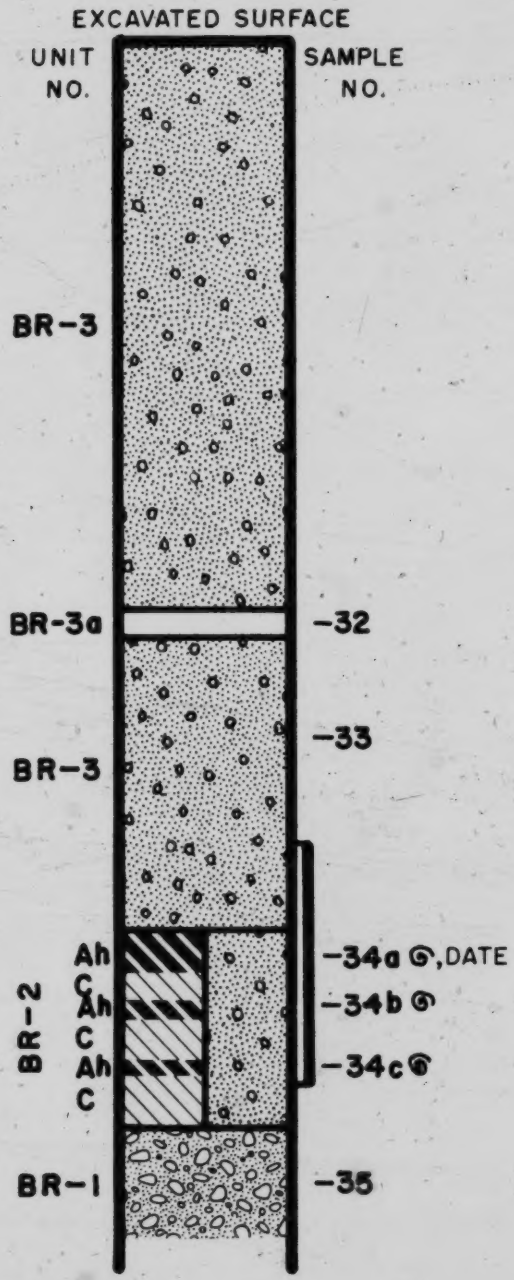


Plate 5

1. Section through the post-glacial sequence at the Bearspaw Dam locality, with an ash (A) and a paleosol (B).
   (shovel for scale)

2. Close-up view of multiple Ah horizons in the paleosol.
   (lens cap for scale)

PLATE 5

1

2

nitrogen value of .084% (Table 3). The C/N ratio is 7.6. The horizon is an Aj. This soil is classified as a Cumulic Humic Regosol.

The unit above the paleosol, BD-4, is 45 cm thick, grayish brown (2.5Y5/2 moist), and is predominantly silty with discontinuous coarse sand lenses throughout. This is an alluvial deposit showing good cut and fill structures, and some low angle crossbeds.

Unit BD-5 (Figure 7) is the ash layer (Plate 5.1). It is 7 cm thick, very pale brown (10YR7/4 moist) and appears concentrated. The ash when analyzed, proved to have a chemical composition coinciding to that reported for Mazama ash (Table 4). The uppermost unit, BD-6, is 106 cm thick. It is an alluvial deposit of interbedded sands and gravels which probably represent a channel environment.

F. Bowfort Road

This section was exposed during the excavation of a land fill site. It is located on the southeast corner of the intersection of Highway 1 and Bowfort Road, west of Calgary (Figure 1). Since the time of sampling, the section has been destroyed. Approximately 3 m of the upper part of the section had already been removed at the time of examination. The site is within the postglacial valley of the Bow River. It is probably the remnant of a high level terrace.

The lowest unit described and sampled is BR-1

Plate 6

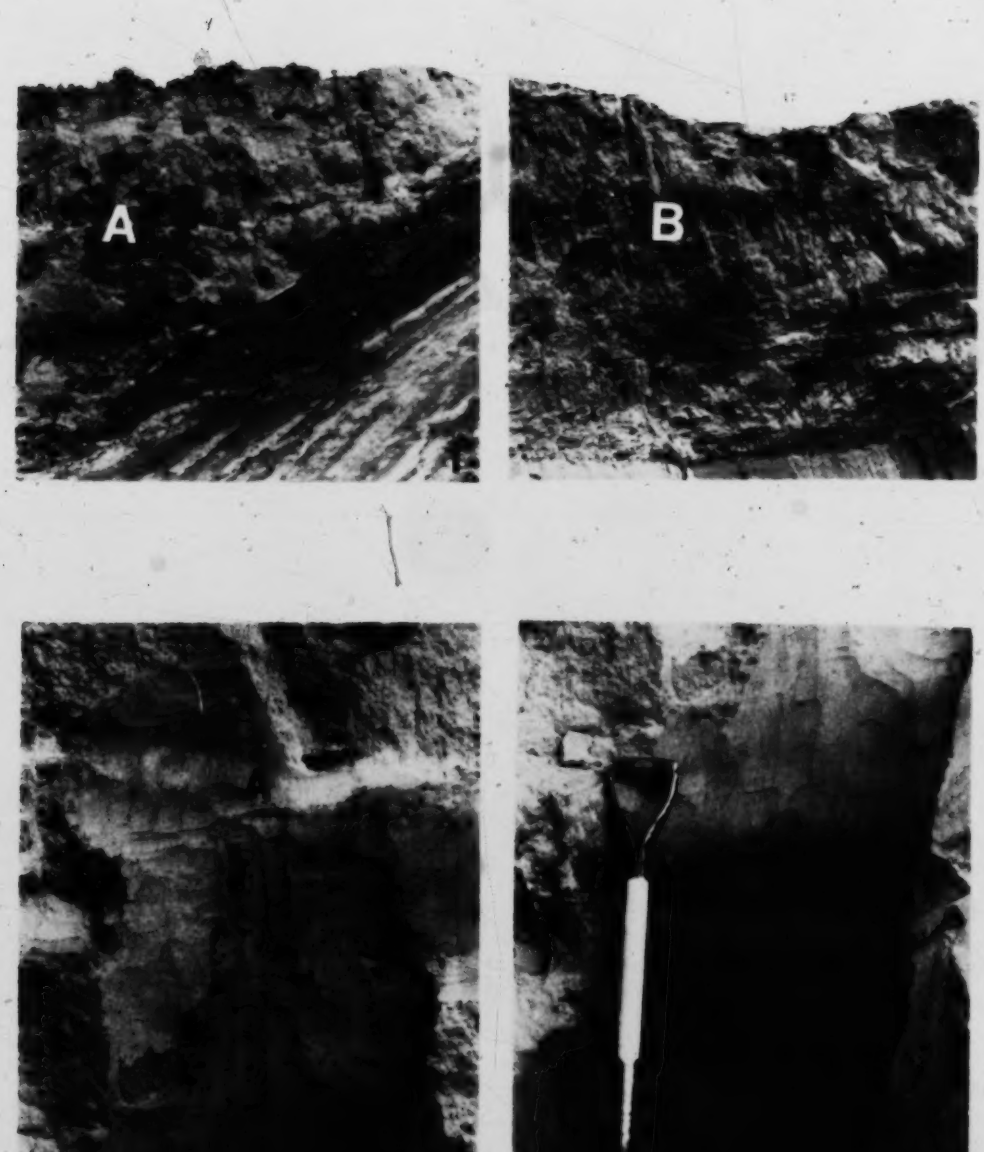
1. View of the Bowfort Road section. Note how easily the ash (A) can be excavated by animals.

2. View of the Bowfort Road section. Note how distinctly the paleosol (B) shows up on the weathered surface.

3. Close-up view of the relationship between the ash (A) and the uppermost A horizon (B) of the paleosol.
(shovel for scale)

4. Close-up view of multiple Ah horizons of the paleosol. The uppermost A horizon (B) is continuous from the Plate 6(3).

PLATE 6



(Figure 8). It is more than 30 cm thick, pale olive (5Y6/3 moist) and is a silty sand. This is an alluvial deposit interpreted from the flat lying, thinly bedded nature of the sediments. This unit is transitional into the overlying unit BR-2. This unit is 57 cm thick and is a sandy silt deposit. The unit is flat lying, with indistinct bedding and intact terrestrial gastropods. This is indicative of a floodplain deposit. Vallonia and Vertigo were found in all samples. They have similar habitats, moist environments associated with floodplains and wooded stream banks. This unit contains the paleosol (Figure 8). The soil itself is distinctly seen on the dry exposed face of the section (Plate 6.2).

The uppermost horizon (Plate 6.3) is 11 cm thick, dark grayish brown (10YR4/2 moist) and massive. The organic carbon content is 0.96% (Table 2) and the nitrogen content is .094% (Table 3). The resulting C/N ratio is 10.2. The horizon is an Ah. Wood fragments collected from this horizon by J.E. Harrison (1973) were dated at 8400±150 years B.P. (Table 5). Below the Ah is a horizon 9 cm thick and light yellowish brown (10YR6/4 moist). It is a C. The second organic horizon is 5 cm thick, dark grayish brown (10YR4/2 moist) and is massive. The organic carbon content is .69% (Table 2) and the nitrogen content is .071% (Table 3), which gives a C/N ratio of 9.7. This horizon is classified as an Ah. Below the second Ah is a 12 cm thick, yellowish brown colour (10YR5/4 moist) C horizon. The lowest

organic horizon is 5 cm thick and very dark brown (10YR3/2 moist). The organic carbon content is .64% (Table 2) and the nitrogen content is .077% (Table 3). This gives a C/N ratio of 8.3. This is a third Ah horizon. A lower horizon is 15 cm thick and a light yellowish brown (10YR6/4). This is a C horizon. The soil can be classified as a Cumulic Humic Regosol.

Above the paleosol is a uniform sequence of sandy silt 260 cm thick, with an ash deposit about 87 cm from the base (Plate 6.3). BR-3 is a massive, light brownish gray colour (2.5Y6/2 moist) unit. It is classified as an alluvial deposit since it is flat lying with indistinct bedding. Unit BR-3a (Figure 8) is the ash layer. There are concentrated pockets of ash within the 8 cm horizon. Shards processed from the ash were analyzed and the chemical composition was found to be similar to that reported for Mazama ash (Table 4).

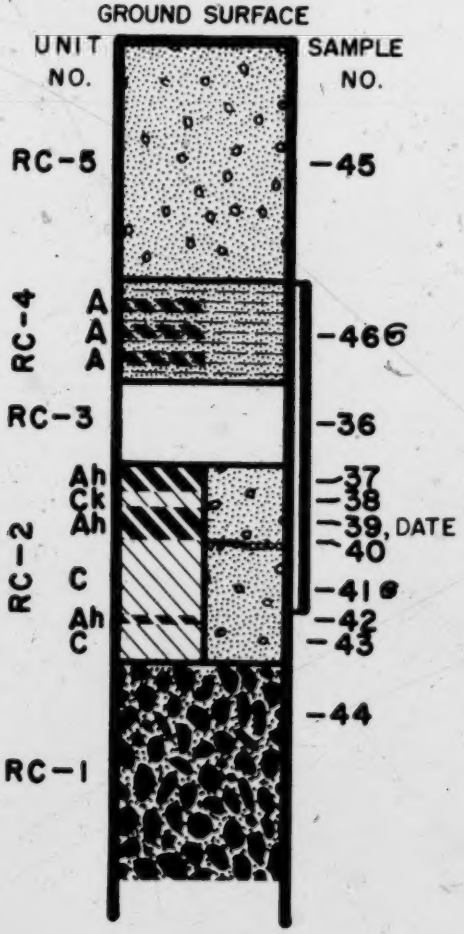
G. Rough Creek

The section at Rough Creek is located in a road cut (Plate 7.1) approximately 20 km east of the Forestry Trunk Road on the Ram River Road (Figure 1). The section is within the foothills and represents the highest postglacial terrace sequence derived from Rough Creek. The stream presently runs along the side of the road opposite the section. The base of the section is approximately 3 m above the level of the

FIG. 9

ROUGH CREEK

NW¼ S2 T39 R12 W5



SCALE 1:20

SEE FIG. 2 FOR LEGEND

FIG. 10

JOFFRE BRIDGE

NE¼ S13 T38 R26 W4

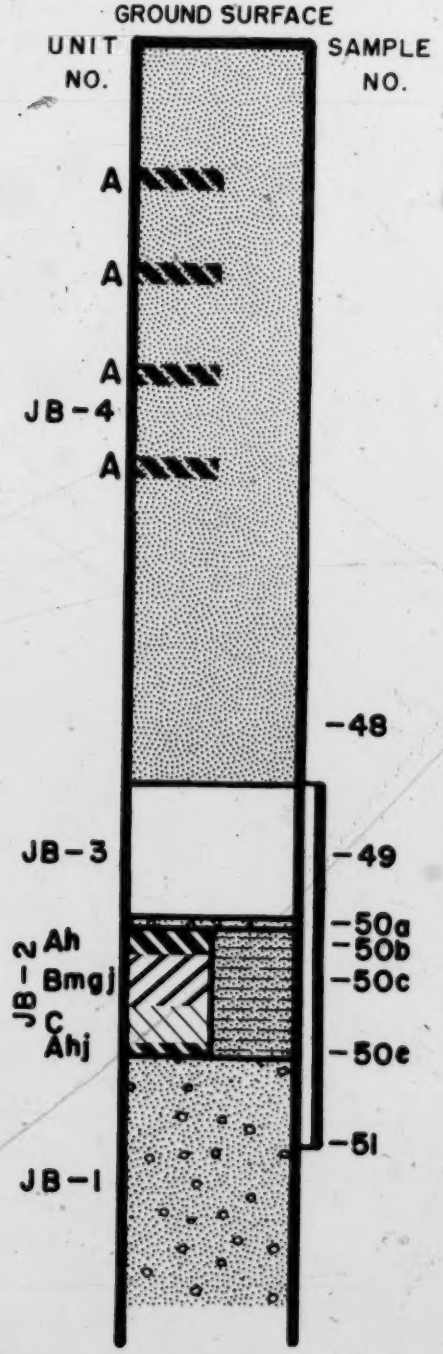


Plate 7

1. Section through the post-glacial sequence at the Rough Creek locality. The weathered surface shows a distinct ash (A).

2. Close-up view of the section showing the relationship between the ash (A) and the paleosol (B). (shovel for scale)

PLATE 7

stream.

The lowest visible unit, RC-1, is greater than 30 cm thick and consists of coarse sands and gravels. The cross bedding and scour and fill structures indicate this is a channel deposit. The unit above the sand and gravel, RC-2, is a predominantly sandy silt with intermittent bands of higher sand content (Table 1). One sample contained intact terrestrial gastropod shells (Figure 9), in particular Vallonia. The ecological implicatons of this genus have been discussed earlier. The variations in texture within this sequence (Table 1) is most likely due to periodic fluctuation in the load capacity of the stream. The evidence seems to indicate that this is a floodplain deposit.

Unit RC-2 overlies RC-1. It is approximately 60 cm thick and has a sandy silt texture (Table 1). It is an alluvial sequence which is flat lying and indistinctly bedded.

The paleosol containing multiple organic horizons (Plate 7.2) is developed in this unit. The upper organic horizon (Figure 9) is 10 cm thick, a very dark grayish brown (10YR3/2 moist) and like all the horizons has a massive structure. The organic carbon content is 1.37% (Table 2) and the nitrogen is .17% (Table 3) . The C/N ratio is 8.1. This horizon is classified as an Ah. The horizon below is 3 cm thick, light yellowish brown (10YR6/4 moist) and has been visibly enriched in carbonate in comparison to the adjacent horizons. This is a Ck horizon. The next horizon is 9 cm

thick and a dark brown colour (10YR4/3 moist). The organic carbon content of this horizon is 1.12% (Table 2) and therefore, the horizon can be classified as an Ah. No nitrogen data was obtained for this horizon. Charcoal from this Ah was collected by Reeves (1974b) and dated at 8030±200 years B.P. (Table 5). Below this Ah is a horizon 22 cm thick. It is a lighter shade of brown (10YR5/3 moist) compared to the overlying Ah. It appears to have a very sandy texture in the upper 3 cm, while the rest of the horizon is texturally identical to the rest of the unit RC-2. This is a C horizon.

The third organic horizon is only 3 cm thick but is quite distinct (Plate 7.2). It is a very dark grayish brown (10YR3/2 moist). No carbon or nitrogen determinations were done but it is most likely an Ah horizon. The lowest horizon varies between 9 and 13 cm in thickness and is brown (10YR5/3 moist). It represents the parent material of the soil and is classified as a C horizon. Therefore, this is a Cumulic Humic Regosol.

Unit RC-3, which overlies the paleosol (Figure 9), is the ash layer. It is 23 cm thick, a pale brown (10YR6/3 moist) and has been irregularly diluted by surrounding alluvium. Analysis of the glass shards show that the chemical composition is the same as that reported for Mazama ash (Table 4).

The unit above the ash, RC-4, is a clayey silt sequence. Multiple organic horizons are found in this 30 cm

unit. Intact terrestrial gastropods such as Vallonia and Retinella were found. This seems to indicate that the deposit is a floodplain sequence, which intermittently dried up and supported vegetation, only to be inundated again. The presence of three articulated bison vertebrae near the top of the middle organic horizon, supports the idea of a low energy fluvial regime.

The uppermost unit, RC-5, is 70 cm thick, light yellowish brown (2.5Y6/4 moist) and has a sandy silt texture. Alternating bands of black and red are noticeable throughout the unit. The bands are very hard and massive in appearance. They seem to be the result of natural fires which burned organic detritus that had grown and accumulated in areas of the floodplain.

H. Joffre Bridge

This section is located 300 m upstream from where the Joffre Bridge crosses the Red Deer River, approximately 8 km east of Red Deer (Figure 1). The exposure is on the north side of the river.

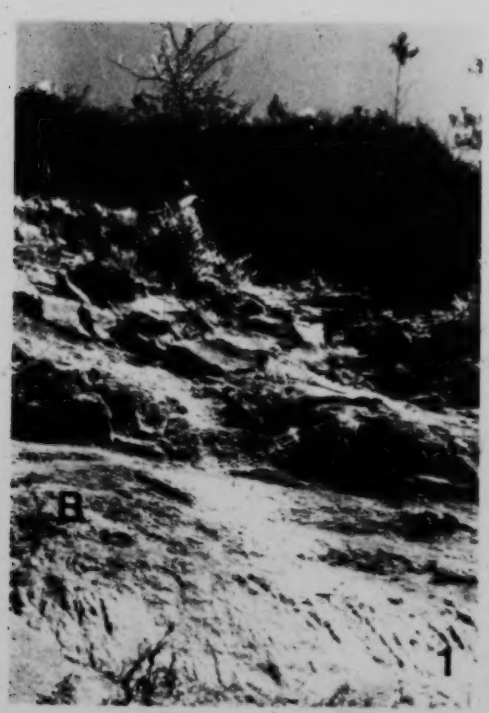
At this site, bedrock is exposed along the lowest part of the section (Plate 8.1). The sandstone unit is immediately overlain by postglacial material. The section represents a high level terrace of the modern day river. At the sampling location (Plate 8.1) the postglacial sequence is 500 cm thick (Figure 10), but thins upstream while the

Plate 8

1. View of the Joffre Bridge section showing an ash (A) and the post-glacial sequence overlying bedrock (B).

2. Close-up view of the Joffre Bridge section showing the relationship between the ash (A) and the paleosol (B).
(shovel for scale)

PLATE 8



sandstone unit thickens.

The lowest unit, JB-1, is .2 m thick, light olive brown colour (2.5Y5/4 moist) and is a sequence of massive sandy silt with virtually no clay fraction (Table 1). The unit appears to grade upward into a more clayey, less sandy unit, JB-2. It is 38 cm thick, with a clayey silt texture (Table 1). This fining upward sequence indicates this is a fluvial sequence. The paleosol is developed in this unit (Plate 8.2).

The upper organic horizon is 8 cm thick, a very dark grayish brown colour (10YR3/2 moist) and is massive. The organic carbon content is 1.08% (Table 2) and the nitrogen is .177% (Table 3). The resulting C/N ratio is 6.1. This is probably a chernozemic Ah. The phytolith data supports this idea. Below this is a 12 to 15 cm thick horizon. It is a yellowish brown colour (10YR5/4 moist) and has a prismatic structure. It is classified as a Bmj horizon and shows evidence of mottling due to a fluctuating water table during soil development. The next horizon is 10 cm thick, and light olive brown (2.5Y5/4 moist). No sample was taken from this horizon because it was too intensely bioturbated, though it has been interpreted as a C horizon.

The weakly developed organic horizon below the C is only 3 cm thick but is easily distinguished (Plate 8.2). It is a dark brown colour (10YR3/3 moist) with an organic carbon content of .71% (Table 2) and a nitrogen content of .081% (Table 3). The resulting C/N ratio is 8.7. This

horizon is an Ah. This soil is classified as a Gleyed Dark Brown Chernozem. The temperature and moisture regime for this soil type were discussed in the section on Fish Creek.

Above the paleosol is a very thin (1 to 2 cm) band of sandy silt (Table 1). It appears to signify the return to a lacustrine environment, which allowed the thick ash layer to develop. Unit JB-3 is 34 to 44 cm thick. The upper boundary is difficult to distinguish since both animals and roots have brought material from above into the ash (Plate 8.2). A sample of the most concentrated white ash (10YR8/2 moist) was processed and the glass shards analyzed. The chemical composition of the shards indicates that this is also Mazama ash (Table 4).

The uppermost unit, JB-4, is 215 cm thick, a pale brown colour (10YR6/3 moist) and contains multiple organic horizons (Figure 10). It has a very silty texture and is indistinctly bedded. The successive organic horizons indicate a floodplain environment, where vegetation flourished during certain periods and was subsequently drowned and new alluvium deposited on top. The modern day profile is most likely an Orthic Black Chernozem. A very high concentration of carbonate has been deposited at the base of this unit (Plate 8.2).

I. Phytoliths and Pollen

Both pollen and phytoliths were extracted from the Ah horizons of the paleosols. The usefulness of these paleoecological indicators was not known in advance but an attempt was made in order to gain as much information as possible.

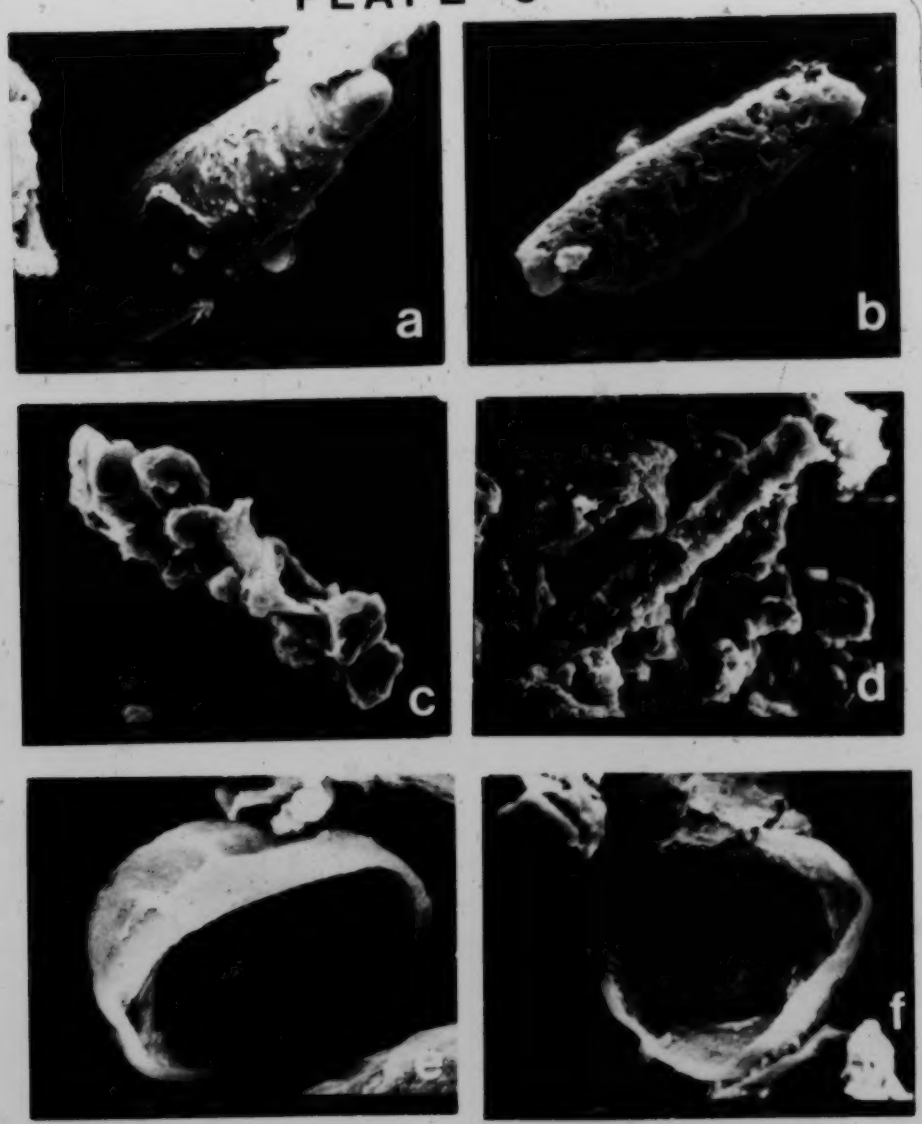
The pollen recovery was very poor. The pollen that was found was so badly degraded that it was unidentifiable. The phytoliths proved to be a much better tool. Since silica is not easily dissolved or eroded, phytoliths appear to stay intact for long periods of time. Each Ah horizon contained phytoliths.

The classes of phytoliths for grasses (Gramineae) as determined by Twiss et al. (1969) are based on the shape of the silica bodies found in the epidermal cells of the plant. Twiss et al. (1969) were able to distinguish four classes, three of which represent distinct subfamilies of Gramineae.

The Elongate class is the one group which appears to be common to all grasses. All five types of these rod shaped phytoliths are found in all types of grasses, whether they are short, tall or domestic. The Panicoid class has 11 types of phytoliths including many varieties of crosses and dumbbells. This class of opal is produced in tall grasses.

The Chloridoid class has two types of saddle shaped phytoliths which are indicative of short grass vegetation. The Festucoid class which includes domestic grasses, contains phytoliths with circular, rectangular, elliptical

PLATE 9



Distinctive Phytoliths

a-b. Elongate Class; 4a. Elongate, Smooth
(a,b. from Ahb horizon at Joffre Bridge)
c-d. Elongate Class; 4b. Elongate, Sinuous
(c. from Ahb horizon at Lethbridge)
(d. from Ahb horizon at Bowfort Road)
e-f. Festucoid Class; 1a. Circular
(e,f. from Ahb horizon at Lethbridge)

Classification after Twiss et. al. (1969)

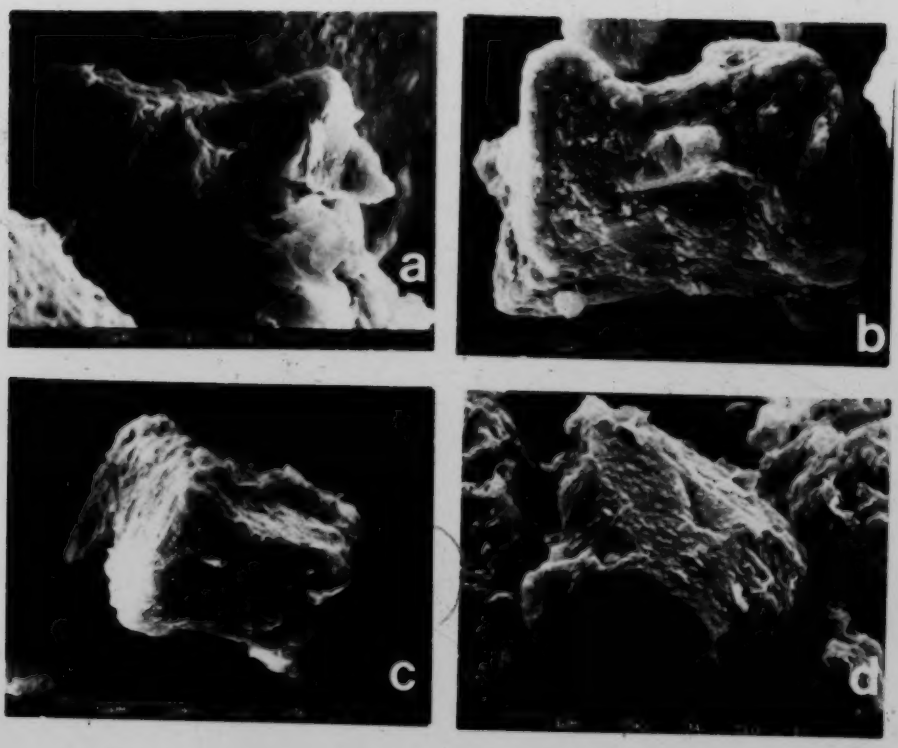
and oblong shapes.

Elongate phytoliths were common in all the samples examined. The best examples are shown in Plate 9. From a few localities (Lethbridge, Joffre Bridge, Willow Creek and Bowfort Road), Festucoid class phytoliths were found. These were all of the circular type and seem to indicate that native domestic grasses were growing during soil formation. The most abundant type of phytoliths were those of the Chloridoid class. These saddle shaped bodies were found in the Ah horizon at every locality and are indicative of a short grass vegetative suite. The most distinct examples are shown in Plate 10. No phytoliths of the Panicoid (tall grasses) class were found in any of the samples. Tall grasses and domestic grasses are present and dominate the modern grassland vegetative suite. This shift from an earlier short grass dominance during postglacial time probably reflects a slight climatic change. The indication of an earlier grassland regime in localities such as Rough Creek and Summit Lake where parkland and forest exist today, supports the idea of a climatic shift.

J. Summary

The postglacial sequence at each locality is basically similar, yet slight differences exist. At Willow Creek, the postglacial sequence overlies a Laurentide till. The lowest unit is a floodplain deposit containing freshwater molluscs,

PLATE 10



Distinctive Phytoliths

a. Chloridoid Class; 2b. Thin Chloridoid
(from Ahb horizon at Bowfort Road)
b-d. Chloridoid Class; 2a. Chloridoid
(b. from Ahb horizon at Callum Creek)
(c. from Ahb horizon at Fish Creek)
(d. from Ahb horizon at Bowfort Road)

Classification after Twiss et. al. (1969)

which are indicative of slow moving shallow waters. A date of 9290±260 years B.P. (Table 5) is reported for gastropods from this unit. The paleosol identified as an Eluviated Black Chernozem, is developed in the upper part of the unit (Figure 3). The soil supported a short grassland vegetative suite as indicated by phytolith identification. The next unit is an alluvial deposit which contains the Mazama ash layer near the base. The uppermost unit is another floodplain deposit, with multiple organic horizons throughout.

Summit Lake (Figure 4) has a basal overbank unit which contains terrestrial gastropods indicative of a floodplain environment. The paleosol is developed in the top of the unit and is classified as a Calcareous Black Chernozem. Again the phytolith data indicated a short grassland vegetation. The Mazama ash layer directly overlies the paleosol, which in turn is overlain by another alluvial unit.

The Lethbridge locality has a till overlain by a proglacial lake sequence at the base of the section. The lowest postglacial unit is an alluvial deposit which contains the paleosol (Figure 5). The soil is classified as a Cumulic Humic Regosol. Phytoliths again show that short grasses were growing on the surface. Above the paleosol is a thick alluvial deposit containing a layer of Mazama ash approximately one third of the way up the unit.

At the Fish Creek site, the basal unit consists of

channel deposits (Figure 6). Above this is a colluvial unit that has the paleosol developed in the upper part. The soil was identified as a Dark Brown Chernozem and was found to contain short grass phytoliths. Overlying the paleosol is another colluvial deposit, which is in turn overlain by the Mazama ash layer. The uppermost unit is an alluvial sequence.

The Bearspaw Dam location has two distinct alluvial units at the base (Figure 7). The overlying unit is a floodplain deposit containing terrestrial gastropods indicative of a moist overbank environment. The paleosol, a Cumulic Humic Regosol, is found in this unit. The soil appears to have supported a short grass vegetation, shown by the phytoliths present. Above the soil is an alluvial sequence, which is overlain by the Mazama ash layer. The uppermost unit is a channel deposit.

The lowest unit at the Bowfort Road section is an alluvial deposit which is overlain by a floodplain deposit (Figure 8). Terrestrial gastropods found in the unit indicate a moist floodplain environment. The paleosol found in this unit is described as a Cumulic Humic Regosol. A date obtained from wood fragments collected from the Ah horizons was reported at 8400±150 years B.P. (Table 5). The phytoliths which were recovered from the soil indicated a short grassland vegetation. The top unit is an alluvial sequence with the Mazama ash layer found about one third of the way up.

At the Rough Creek locality, the basal unit is composed of channel sands and gravels. The overlying unit is a floodplain deposit containing terrestrial gastropods, which have a moist overbank habitat. The paleosol, a Cumulic Humic Regosol, is in this unit (Figure 9). The phytolith material collected was indicative of short grass vegetation. Charcoal from the paleosol was dated at 8030±200 years B.P. (Table 5). Above the paleosol is the Mazama ash layer, which is overlain by two floodplain sequences. Terrestrial gatropods indicative of a moist floodplain environment were found in the lower of the two units. A number of organic rich horizons are present in both units.

The lowest postglacial unit at Joffre Bridge is a fluvial sequence in which the paleosol is developed. The soil was classified as a Gleyed Dark Brown Chernozem, which supported a short grass vegetative suite shown by the phytolith material. Overlying the paleosol is a thick Mazama ash layer. Above the ash is a floodplain deposit containing multiple organic horizons.

IV. Reconstruction and Discussion

A. Postglacial History and Chronology

In Southern Alberta, the last glaciers retreated sometime before 10000 years B.P. As drainage re-established its present day pattern, fluvial and lacustrine deposits formed over the recently laid down glacial drift. In many instances, the rivers follow their preglacial course. From the sections studied, it is evident that the basal postglacial unit represents a distinct fluvial facies. The carbon 14 date from the alluvial deposit at Willow Creek of 9290±260 years B.P. (Table 5) shows that postglacial drainage was established by this time. Between the time of glacial retreat and the time of deposition of Mazama ash at 6600 years B.P. (Fryxell, 1965), a period of non-deposition existed in the western part of Alberta. This is indicated by the widespread development of soils. These soils, whether they are highly developed such as the ones at Summit Lake and Willow Creek, or weakly developed such as the ones at Bearspaw Dam and Rough Creek, show that regular alluvial deposition was interrupted or decreased to infrequent periods of flooding. The establishment of vegetation and the resulting pedogenic development support the idea of decreased fluvial activity. The fact that alluvial deposition resumed immediately prior to Mazama ash deposition makes a strong case for these soils being penecontemporaneous. The carbon 14 dates obtained by others

for the Ah horizons at Rough Creek and Bowfort Road (8030±200 years B.P., Reeves, 1974b; and 8400±150 years B.P., Harrison, 1973; respectively) (Table 5) supports the premise of a depositional hiatus during this period. The soils are a prairie grassland type and the phytolith suite indicates grassland vegetation, even in areas where grassland vegetation no longer exists; i.e. Rough Creek and Summit Lake. This time of soil development and associated grassland vegetation shows that formerly active floodplains in western Alberta experienced a period of nondeposition. This appears to indicate a time of drier, warmer conditions in Southern Alberta and is probably related to the Altithermal Interval of Western Canada. In areas bordering this region, the Holocene stratigraphy and paleoenvironments may be different and vary from place to place.

After deposition of Mazama ash, alluviation resumed, resulting in the various fluvial deposits found overlying the tephra layers. With time, as base level lowered the meandering rivers downcut to their present position.

There appears to be no other widespread period of soil development in the postglacial floodplain sequences after Mazama ash deposition until the present. Weakly developed A horizons found above the Mazama ash layer can be seen in four of the sections, (Willow Creek, Fish Creek, Rough Creek and Joffre Bridge), yet these are very minor and probably represent periods when the floodplains briefly supported vegetation.

B. Correlation with Similar Sequences

Five other localities with paleosols developed under Mazama ash have been described by others. A section in the Livingston Gap (Figure 1) was uncovered by Reeves and Dormaar (1972) during an archeological investigation. The section contained multiple soils. One was below an ash. The ash was identified by J.A. Westgate as Mazama and the soil identified as an Orthic Regosol (Dormaar 1972). Dormaar, in studying the infrared spectra of humic acids in the Ah horizon of this soil, concluded that the absorption spectra was typical of grassland vegetation. This is in contrast to the spectra obtained from the Ah horizon of the Degraded Alpine Eutric Brunisol immediately below the Orthic Regosol. This spectra indicated a forest vegetation with an open canopy. This conclusion was supported by the results of the infrared spectra of the peroxidized humic acids.

Two carbon 14 dates (9570±240 years B.P., 8050±150 years B.P., Table 5), obtained from an archeological living floor associated with the Ah horizon of this lower soil give control in estimating the time of formation of the upper grassland soil, since the overlying Mazama ash gives an upper date of 6600 years B.P. The modern soil in this area is an Orthic Eutric Brunisol and supports a forest vegetation. Obviously, some change in environment occurred during mid-postglacial time.

The Bow River Bridge Section is located at the intersection of the Trans Canada Highway and the Bow River

in Calgary. It has been described by Wilson (1974) and is practically identical to the section described at Fish Creek. The soil is developed in alluvium 32.5 cm below the Mazama ash layer. It also is very similar to another section described by Wilson (1974) at the Mona Lisa site, Calgary (Figure 1). The Mona Lisa location is a Paleo-Indian bison kill site, discovered during urban excavation. The kill site is represented by a thick bone bed, overlain by Mazama ash, and underlain by a paleosol 35 to 40 cm below. A carbon 14 date on the bone material is 8080±150 years B.P. (Table 5). Alluvial material separates the two units.

A section at Callum Creek (Figure 1) has been described by N.W. Rutter. At this locality, a paleosol is developed in an alluvial deposit approximately 34 cm below Mazama ash. A fifth section has been described by Pawluk and Dumanski (1969), at the Beverly location in Edmonton (Figure 1). The pattern again is a paleosol under Mazama ash. The paleosol shows the characteristics of a Black Chernozem.

All of the sections discussed support the idea of an area-wide depositional hiatus resulting in encroachment of grassland vegetation onto the floodplains. This period of stability must have lasted long enough for pedogenic processes to become established, resulting in development of soil profiles.

C. The Altithermal

Conceptual Development

It has already been discussed that a period of stability resulting in the establishment of widespread grassland vegetation and associated pedogenesis occurred in Southern Alberta between 6600 and 9000 years B.P. This period can be considered the Altithermal Interval in Western Canada. The concept of a postglacial Altithermal has been controversial fot many years.

The warm period was first recognized by botanists and marine zoologists. It was used to explain certain floristic anomalies during the postglacial period. In 1824, in Norway, F.W. Ehreheim noted that trees once grew above the present tree line. Workers in the Shetland Isles, North America, Sweden, Northern Ireland and Denmark all recognized the same phenomenon and each concluded that their area had been warmer than present sometime during the mid-postglacial. It has been through the work of geologists and botanists from Scandanavia, such as: Blytt, Sernander, von Post, Gunnar Anderson and Nathorst, that the past climatic phenomena has become better known.

In 1881, Blytt, in Norway, formulated a scheme based on typological succession and peat stratigraphy. Sernander added his opinions, resulting in the Blytt-Sernander postglacial climatic sequence hypothesis. It started with initial glacial retreat in Sweden. It has six distinct stages, each of which was correlated with the various high

and low water stages of the Baltic basin.

Using palynology, L. von Post devised a broader hypothesis for postglacial climatic succession. He divided the postglacial into three phases on the basis of temperature rather than moisture. His system appears to have been enlarged upon by Antevs (1948). Thus, there are two models for climatic change; first, the indistinct transitional model of von Post and Antevs and second, the episodic model of Blytt and Sernander. Antevs' idea of the Neothermal or postglacial period was to divide it into three subunits, similar to von Post.

1. The Anathermal, increasing warmth.
2. The Altithermal, maximum warmth.
3. The Medithermal, decreasing warmth.

The Altithermal represents drier and warmer conditions than at present. The actual dates set on these units by Antevs are open to debate since they are based on very general principles, i.e. it takes 4000 years to fill a lake. These dates were also based on an early incorrect date for Mazama ash.

Antevs' idea of a world-wide Altithermal has also been questioned. Radiocarbon dating of these phases show that they cannot be projected world-wide. Bryson, Baerreies and Wendland (1970), using a computer, analyzed 620 carefully selected radiocarbon dates from the last 10000 years. The dates were picked from those reported by investigators as being environmentally significant. The conclusion of this

study was to show that climatic events around the world have occurred at discreet times. Their results seem to support the Blytt-Sernander climatic model.

The Altithermal of Western Canada

In spite of arguments as to the actual climatic model, most workers agree that an Altithermal occurred sometime during mid-postglacial time. Mainly through pollen studies, the Altithermal has been recognized in Northwestern North America and the Cordillera. Wright (1971), in studying the changes in vegetation succession across North America, shows that the West was under a warmer and drier regime approximately 8000 years B.P., which he found to be earlier than in the Eastern part of the continent. Many workers have derived a similar date for a warmer, drier period in the western part of the continent.

In Alberta extensive palynological evidence for an Altithermal Interval during the mid-postglacial has been found. D. Emerson (University of Alberta, pers. commun., 1979) has basal dates from cores of Hastings Lake, east of Edmonton, of 4580±190 years B.P. and 4450±215 years B.P. Another, deeper core from North Hastings Lake gave a basal date of 6180 years B.P. A basal date from a bog in Elk Island Park 54 km east of Edmonton was 4180±70 years B.P. and a date of 3970±170 years B.P. was given on bottom sediments in a nearby pond (C. Schweger, University of Alberta, pers. commun., 1979).

A sample from a small lake near Alberta Beach 76.5 km west of Edmonton was dated at 7380±245 years B.P. (C. Schweger, University of Alberta, pers. commun., 1979). Three other basal dates from lake cores in the Edmonton area indicate that the lakes are less than 10000 years old. Baptiste Lake 4950±100 years B.P. (on lowest organic layer); Lac. St. Anne 5630±125 years B.P; Lake Isle 9530±120 years B.P. A date of 6240±175 years B.P. was also obtained from the bottom of a bog near Lake Wabamun (C. Schweger University of Alberta, pers. commun., 1979). The young basal dates of these cores seem to indicate that the lakes in the area filled their present day basins sometime between 3970±170 years B.P. and 7380±245 years B.P. This is thought to represent increasing moist conditions signalling the end of the Altithermal. The older date of 9530±120 years B.P. (Lake Isle) may have resulted from the fact that the lake never dried up, though, evidence for a more saline period is found in the pollen record (T. Habgood, University of Alberta, pers. ccmmun., 1979).

Ritchie (1976) summarized pollen data and radiocarbon dates from 16 sites across Western Canada. Comparisons of the sites showed a definite pattern. An abrupt change from a spruce forest to a grassland environment seems to have occurred approximately 9500 years B.P. at around 52°N latitude. This vegetation was subsequently replaced by the southward movement of boreal forest vegetation. This appears to be during the late postglacial at around 5500 years B.P.

At particular localities, Ritchie mentions a lowering of the water table between 8000 and 7000 years B.P. He felt that this was a result of a drier climate.

Fritz and Krouse (1973) found that the oxygen 18 content of the mollusc and ostracod shells from Wabamun Lake showed a very definite period of increase and decrease during the last 10000 years. An ash which was originally thought to be Mazama, was later shown to be an older layer, approximately 10500 years B.P. This would result in the interval of warming and increased oxygen uptake by these shells between 6500 and 8500 years B.P. The trend of decreasing oxygen 18 content seems to have continued from this time until almost the present.

Harris and Pip (1973) looked at molluscs from lacustrine and alluvial deposits in Alberta. Using 55°N as a dividing line, they examined the ratio of present day molluscs living in these two areas, to those living there in the past. They found that many species no longer live north of 55°N but have in the past. They recognized three major climatic periods. First, a warming period, which was more moist than today and lasted from the time of glacial retreat until 9000 years B.P. Their second period is a warmer but drier interval extending from 9000-7000 radiocarbon years B.P. They felt this period represented the maximum of the Altithermal Interval. From that time to the present, conditions have been trending more to a cooler and drier climate.

In areas surrounding Alberta, evidence also supports the theory of a mid-postglacial Altithermal Interval. Mack et al. (1978b) studied the pollen sequences from postglacial material in Idaho and Washington states. At Hager Pond, Bonner Co. Idaho, they recognized five pollen zones. Pollen zone 2 represented a warmer, drier period during the postglacial and was recognized by an influx and increase of grass (Gramineae) with diploxylon pine. They felt this warming trend started about 8300 years B.P. and lasted until 7600 years B.P. In the Sandpoil River Valley, Washington, the same authors (1978) found that evidence for a long warm period (9000-3000 years B.P.) was present in the pollen record.

Grigal, Severson and Goldz (1976) examined a sequence of buried soils in North Central Minnesota. The results of soil morphology studies and radiocarbon dating indicate that a large dune field was active in the area during a time of peak warmth and dryness at approximately 7000 years B.P.

In the Okanagan Valley of central British Columbia, Alley (1976) found evidence for a warmer, drier period starting around 8400 years B.P. Alley's conclusion was based on the pollen zonation from the Kelowna bog. The KB2 zone in particular shows an influx of grasses (Gramineae) and sagebrush (Artemisia). The date of the influx was calculated using sedimentation rates.

In the northern part of Canada, Delorme et al. (1977) studied the ostracod and mollusc assemblages. They concluded

that postglacial climates oscillated between warmer and cooler periods than the present and that the thermal maximum was a world-wide phenomenon. The authors also reported the expansion of beaver habitat and population northward into areas which are today either unsuitable or marginal for the animal. This expansion occurred between 7000 and 9000 years B.P. Mackay (1978) in his discussion of Delorme et al. (1977) interprets the field evidence as supporting the idea that mean annual air temperature has not risen above 0°C in Canadian coastal areas during the entire postglacial. He does mention that a widespread thaw unconformity is found truncating glaciated Pleistocene deposits. Organic material overlying the unconformity has been radiocarbon dated as between 9180±110 years B.P. and 7950±280 years B.P.

McCulloch and Hopkins (1966) in examining fossil wood of a size and speciation not presently found in the coastal tundra area of north-west Alaska concluded that a warm interval occurred between 10000 and 8300 years B.P. Again, they found evidence of beaver habitation far beyond the range of modern beaver. Evidence of ice wedge melting and buried soils in penecontemporaneous deposits also supports their interpretation.

Heusser (1973, 1974) studied the retreat of the Juan de Fuca Lobe and the re-establishment of vegetation on the Olympic Peninsula, Washington. From pollen data and radiocarbon dates Heusser constructed a postglacial environmental sequence. His P-1 zone, represented by a

Pinus-Alnus-Picea assemblage flourished under a cool, relatively humid climate from 10000 to 8000 years B.P. A warming trend which reached a maximum between 6080±100 years B.P. and 8660±120 years B.P. was identified by a Alnus-Picea -Pseudotsuga-Pteridium assemblage. The total Altithermal interval is reported as 3000 to 8000 years B.P., which includes a period of climatic deterioration. The third pollen zone P-3 of Tsugaheterophylla-Picea-Thuja indicates the establishment of hygrophilous species during the past 3000 years. This vegetation thrives in the cooler, moister, typically oceanic environment present today.

Hansen and Easterbrook (1974) also support the idea of a warmer, drier interval from 9920±760 years B.P. to approximately 7000 years B.P. They based their interpretation on pollen assemblages found in bogs in the Puget Lowland. Their pollen data indicates that after 7000 years B.P. the climate became moister and cooler.

Mathewes and Rouse (1975) again found three postglacial assemblage pollen zones in the lower Fraser River Canyon of British Columbia. The earliest postglacial vegetation appeared to grow under fairly cool and moist conditions. The transition to the second zone seems to have occurred around 10400 years B.P. and include certain noteable changes in the vegetative suite. The pollen of Gramineae, Pteridium and Artemisia began to increase and reached their peak at about 8620±135 years B.P. The presence of this assemblage indicates a climate that was warmer and drier than the

previous one. Immediately below the Mazama ash unit, the pollen assemblage begins to show an increase in the abundance of Tsugaheterophylla, Abies and Betula. This seems to indicate a return to moister, cooler conditions.

In summary, much of the support for the idea of an Altithermal interval in Western Canada is based on the many pollen sequences studied. The pollen assemblage zones, workers have defined, indicate that between 9500 and 6500 years B.P., a vegetative suite responding to warmer drier conditions moved into areas where the vegetation showed previous dependence on cooler moister conditions. After this time, the vegetation appears to shift back again to species responsive to a cooler moister climate.

There is additional evidence indicating that beaver, as well as certain species of ostracods and molluscs, have lived in more northern habitats than they do today. The dates of these occupations coincide with the interval determined by the pollen record. Futhermore, it can be shown that during this period, certain species of trees invaded areas farther north than their present known limit. Evidence of lowered water tables, extensive dune activity and the presence of a thaw unconformity in the Arctic, all indicate that a shift towards a warmer drier climate occurred between 9500 and 6500 years B.P.

In this particular study, the use of paleosols to obtain paleoenvircnmental information and to aid in geologic reconstruction, proved most successful. The information

gathered supports the concept of an Altithermal interval in Western Canada between 8500 and 6600 years B.P. These dates agree very favourably with the interval established by other workers.

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Appendix I

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Processing Sediments for Pollen

1. Weigh out 10-15 gm of sediment into 100 ml beaker. Add 25 ml of 10% NaOH, stir well with wooden stirring rod, boil gently with constant stirring on hot plate for 5 minutes. Filter immediately through a fine screen (coarse screen if sediment is very peaty) into 150 ml beaker, retaining sand and coarse particles in original beaker. Add 10 ml distilled water to coarse fraction of sediment remaining in beaker, stir, then swirl for 60 seconds. Allow to settle for exactly 30 seconds, pour supernatant suspension onto screen. Repeat with a second portion of 10 ml of distilled water. Wash the fine sediment on the screen with a few drops water. Transfer contents of beaker to Nalgene centrifuge tubes, balance the tubes by means of centrifuge-tube balance, centrifuge, decant supernatant liquid. Wash sediment in bottom of centrifuge tube with 10 ml of water to which a few drops of 10% NaOH have been added, balance tubes, centrifuge, decant. Repeat if necessary until supernatant liquid is no longer heavily coloured by humates.
2. Add a few drops of conc. HCl to the sediment, stir well. When the initial reaction has subsided, add a little

more HCl, stir again. Continue adding HCl until no further effervescence occurs, balance tubes, centrifuge. Decant.

3. Add about 15 ml of $ZnBr_2$ soln. (sp. gr. 1.8 - 2.0), stir. Balance centrifuge tubes. Stopper tube with rubber stopper, shake gently and release any accumulated pressure. Stopper again, shake for exactly 3 minutes, then centrifuge for 20 minutes. Carefully filter with suction the zinc bromide solution through glass filter paper in Nalgene Buchner funnel. Do not discard the filtrate; pour the filtrate into the bottle labelled "Used $ZnBr_2$". Roll up the filter paper on which the pollen is now deposited, place the wad in clean Nalgene centrifuge tube.
4. CAUTION: USE MASK, GLOVES and APRON. DO NOT BREATHE VAPOURS. Cautiously add a few drops of hydrofluoric acid (HF), swirl. When the violent reaction subsides, add a little more HF, swirl again. Add a total volume of 15-20 ml HF, stir with clean wooden stirring rod, loosely stopper with Nalgene stoppers, heat in boiling water bath on hot plate for 1 hour. Allow to stand at room temperature in hood overnight.
5. Centrifuge, decant, add 10 ml conc. HCl, stir thoroughly, allow to boil in water bath on hot plate for 5 minutes, cautiously stirring once during the 5 minute period. Centrifuge while still hot, decant. Repeat process at least six times.

6. (Transfer if desired to 15 ml glass centrifuge tube). Wash with 10 ml distilled water, centrifuge, decant. Wash with 10 ml glacial acetic acid, centrifuge, decant.
7. Acetolysis, etc. (as for peat samples).

Processing Peat for Pollen

1. Place peat sample in 100 ml beaker. Add 20 ml of 10% NaOH, stir well with wooden stick, boil gently with constant stirring on hot plate for 5 minutes. Allow to cool, pour off supernatant through fine screen into 150 ml beaker, retaining most of the peat in the original beaker. Wash peat in beaker with several 10 ml portions of distilled water, pouring off supernatant each time through screen. Transfer the liquid to Nalgene centrifuge tube, centrifuge, decant. Wash material in bottom of tube with water to which a few drops of 10% NaOH have been added. Centrifuge, decant. Repeat if necessary until supernatant is straw coloured.
2. Wash with 10 ml glacial acetic acid (transfer if desired to 15 ml glass centrifuge tubes).
3. CAUTION: make up acetolysis mixture. Measure out the desired multiple of 9 ml of acetic anhydride into 125 ml flask. To this, add cautiously in several portions with swirling, the desired multiple of 1 ml conc. H_2SO_4.
4. Add 10 ml of acetolysis mixture to centrifuge tube. Stir well with clean stick. Heat for 3-5 minutes in boiling water bath on hot plate. Cool. Centrifuge, decant.
5. Wash with 10 ml glacial acetic acid. Centrifuge, decant.

6. Wash with 10 ml distilled water. If it is desired to stain grains, add several drops of Safranin-O at this stage. Centrifuge, decant.
7. Wash with water to which a few drops of 10% NaOH have been added. Centrifuge , decant.
8. Wash with 10 ml of 98% ethyl alcohol. Centifuge, decant.
9. Wash with 10 ml of acetone. Centrifuge, decant.
10. Suspend the pollen in a few mls of acetone, pour into vial, wash tube with a few drops of acetone, pour into vial. To vial add 2-3 drops of glycerol, allow to evaporate overnight. If necessary add more glycerol and mount on microscope slide.
11. Alternatively, add a few drops of glycerol to the pollen in the centrifuge and transfer to the vial by means of a disposable pipet. Mount on slide.

Appendix II

(from the Canadian System of Soil Classification, 1978)

Chernozemic Order

The general concept of the Chernozemic order is that of well to imperfectly drained soils having surface horizons darkened by the accumulation of organic matter from the decomposition of xerophytic or mesophytic grasses and forbs representative of grassland communities or of grassland-forest communities with associated shrubs and forbs. The major area of Chernozemic soils is the cool, subarid to subhumid Interior Plains Region of western Canada. Minor areas of Chernozemic soils occur in some valleys and mountain slopes in the Cordilleran Region extending in some cases beyond the tree line. Most Chernozemic soils are frozen during some period each winter and their sola are dry at some period each summer. Their mean annual temperature is higher than 0°C and usually less than 5.5°C, but some Chernozemic soils in dry valleys of British Columbia have higher temperatures.

The specific definition is as follows: Soils of the Chernozemic order have an A horizon in which organic matter has accumulated (Ah, Ahe, Ap) that meets the requirements of a chernozemic A horizon. A chernozemic A has the following properties:

1. It is at least 10 cm thick.
2. Its color value is darker than 5.5 dry and 3.5 moist and

its chroma is less than 3.5 moist.

3. Its color value is at least one Munsell unit darker than that of the IC horizon.
4. In soils disturbed by cultivation or other means, the Ap horizon must be thick and dark enough to provide 15 cm of surface material that meets the color criteria given in 2 and 3 above.
5. It contains between 1% and 17% organic carbon and its C/N ratio is less than 17.
6. Characteristically it has sufficiently good structure that is is neither both massive and hard nor single grained when dry.
7. Its base saturation (neutral salt) is more than 80% and calcium is the dominant exchangeable cation.
8. It is restricted to soils having a mean annual temperature of 0°C or higher and a soil moisture subclass drier than humid.

Chernozemic soils may have an Ae horzon and a Bm or a Bt horizon. They do not have any of the following: solonetzic B, podzolic B, evidence of gleying strongly enough expressed to meet the criteria of Gleysolic soils, permafrost within 2 m of the surface.

Dark Brown

These Chernozemic soils have A horizons somewhat darker in color than soils of the Brown great group. Dark Brown soils usually occur in association with a

native vegetation of mesophytic grasses and forbs in a semi-arid climate. In virgin areas the Ah horizon is usually darkest at the surface and becomes progressively lighter in color with depth.

Specifically, Dark Brown soils have the characteristics specified for the order and a chernozemic A horizon with a color value darker than 3.5 moist and between 3.5 and 4.5 dry. The chroma of the chernozemic A horizon is usually greater than 1.5 dry. The soil climate of this great group is typically cold (rarely mild) semiarid.

Orthic Dark Brown

Common horizon sequence: Ah, Bm, Cca or Ck

The Orthic Dark Brown subgroup may be thought of as the central concept of Dark Brown soils. It encompasses the properties specified for the Chernozemic order and the Dark Brown great group. Usually Orthic Dark Brown soils have brownish colored, prismatic B horizons and light colored horizons of carbonate accumulation similar to those of Orthic Brown soils.

Specifically, Orthic Dark Brown soils are identified by the following properties:

1. They have a chernozemic A horizon with a color value darker than 3.5 moist and between 3.5 and 4.5 dry.
2. They have a B horizon (Bm, Btj, Bt) at least 5 cm thick that does not contain alkaline earth

carbonates.

3. They lack an Ae horizon 2 cm thick or more.
4. They lack a Bnjtj horizon or a similar horizon characteristic of inter-grades to the Solonetzic order.
5. They lack evidence of gleying as indicated by faint to distinct mottling within 50 cm of the surface.

Gleyed Dark Brown

Common horizon sequence: Ah, Bmgj, Cgj or Ckgj

These soils have the general properties specified for the Chernozemic order and the Dark Brown great group. They differ from the Orthic Dark Brown subgroup in having weakly expressed features of gleying. Specifically, faint to distinct mottles indicative of gleying occur within 50 cm of the surface.

Black

These Chernozemic soils have A horizons darker in color and commonly thicker than soils of the Brown and Dark Brown great groups. Black soils usually occur in association with a native vegetation of mesophytic grasses and forbs or with mixed grass, forb and tree cover. Some Black soils occur under alpine grass and shrub vegetation.

Specifically, Black soils have the characteristics specified for the order and a chernozemic A horizon with a color value darker than 3.5 dry. The chroma of the

chernozemic A is usually 1.5 or less, moist. The soil climate of this great group is typically cold (rarely mild) subhumid.

Orthic Black

Common horizon sequence: Ah, Bm, Cca or Ck

The Orthic Black subgroup may be thought of as the central concept of Black soils. It encompasses the properties specified for the Chernozemic order and the Black great group. Usually Orthic Black soils have brownish colored, prismatic B horizons and light colored horizons of carbonate accumulation similar to those of Orthic Brown soils.

Specifically, Orthic Black soils are identified by the following properties:

1. They have a chernozemic A horizon with a color value darker than 3.5 moist and dry.
2. They have a B horizon (Bm, Btj, Bt) at least 5 cm thick that does not contain alkaline earth carbonates.
3. They lack an Ae horizon 2 cm thick or more.
4. They lack a Bnjtj horizon or a similar horizon characteristic of inter-grades to the Solonetzic order.
5. They lack evidence of gleying as indicated by faint to distinct mottling within 50 cm of the surface.

Calcareous Black

Common horizon sequence: Ah, Bmk, Cca or Ck

These soils have the general properties of the Chernozemic order and the Black great group. They differ from the Orthic Black subgroup in having a B horizon from which primary alkaline earth carbonates have not been removed completely (Bmk). Otherwise, they have the general properties of Orthic Black soils.

Eluviated Black

Common horizon sequence: Ah, Ae, Btj or Bt, Cca or Ck

These soils have the general properties of the Chernozemic order and the Black great group. They differ from the Orthic Black subgroup in having an eluvial horizon or horizons 2 cm thick or more (Ahe, Ae, Aej) usually underlain by a weakly to moderately developed illuvial Btj or Bt horizon.

Regosolic Order

Regosolic soils are weakly developed, the lack of development of genetic horizons may be due to any of a number of factors: youthfulness of the material - recent alluvium; instability of the material - colluvium on slopes subject to mass wasting; nature of the material - nearly pure quartz sand; climate - dry, cold conditions. Regosolic soils are generally rapidly to imperfectly drained. They

occur under a wide range of vegetation and climates.

Specifically Regosolic soils have horizon development too weak to meet the requirements of soils of any other order. Thus they have none of the following: solonetzic B, Bt, podzolic B, Bm 5 cm thick or more; evidence of gleying strong enough to meet the requirements of Gleysolic soils; organic surface horizons thick enough to meet the requirements of Organic soils; permafrost within 1 m (2 m if strongly cryoturbated). They may have LFH or O horizons and they may have Ah horizon as follows:

1. Less than 10 cm thick, or
2. Any thickness if there is no underlying B horizon 5 cm thick or more and the Ah horizon does not satisfy the criteria of a chernozemic A.

Regosol

These are Regosolic soils that do not have an Ah horizon 10 cm thick or more at the mineral soil surface. They may have buried mineral-organic layers, and organic surface horizons. They do not have a B horizon 5 cm thick or more.

Orthic Regosol

Common horizon sequence: C

These soils have the properties specified for the Regosolic order and the Regosol great group. Specifically they are identified by the following properties:

1. If they have an A horizon, it is less than 10 cm thick.
2. There is either no B horizon present, or the B horizon is less than 5 cm thick.
3. They have a low content of organic matter throughout the control section; this is reflected in a uniform color, with color value differences between layers being less than one Munsell unit.
4. They are well drained and lack any evidence of gleying within the upper 50 cm.

Cumulic Regosol

Common horizon sequence: C Ahb C

These soils have the properties specified for the Regosolic order and the Regosolic great group. They differ from the Orthic Regosol subgroup in having either, from the surface or below any thin Ah horizon, layers that vary in color value by 1 or more units, or organic matter contents that vary irregularly with depth. They lack evidence of gleying within 50 cm of the mineral surface. Commonly, these soils result from intermittent flooding and deposition material.

Humic Regosol

These are Regosolic soils that have an Ah horizon 10 cm thick or more at the mineral soil surface. They may have organic surface horizons and buried mineral-organic horizons. They do not have a B horizon

5 cm thick or more.

Orthic Humic Regosol

Common horizon sequence: Ah, C

These soils have the properties specified for the Regosolic order and the Humic Regosol great groups. Specifically, they are identified by the following properties:

1. They have an Ah horizon 10 cm thick or more.
2. Either they have no B horizon or the B horizon is less than 5 cm thick.
3. They have a low content of organic matter throughout the control section below the A horizon; this is reflected in a uniform color, with differences of Munsell color value of less than 1 unit between layers.
4. They lack faint to distinct mottling indicative of gleying within the upper 50 cm.

Cumulic Humic Regosol

Common horizon sequence: Ah, C, Ahb, C

These soils have the properties specified for the Regosolic order and the Humic Regosol great group. They differ from the Orthic Humic Regosol subgroup in having, below the Ah horizon, layers that vary in color value by 1 or more units, or organic matter contents that vary irregularly with depth. They do not have faint to distinct mottles indicative of gleying within 50 cm of

the mineral surface. Commonly these soils result from either mass wasting of soil downslope or intermittent flooding and deposition of material.